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A pilot evaluation of technology –enabled active learning through a Hybrid Augmented and Virtual Reality app

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ABSTRACT

This paper reports on students' learning experience with a hybrid Augmented Reality (AR) and Virtual Reality (VR) app called the Kuching Heritage App (KHA). We investigated the effect of visualisations, time lapse (i.e., past to present), and the witnessing of historical changes on students' learning experience about cultural heritage. This pilot study utilised a mixed methods approach with an initial Technology-Enabled Active Learning (TEAL) Inventory distributed to 59 students, followed by semi-structured interviews with five student participants. Overall, the participants responded positively to the TEAL questionnaire's four domains, particularly in the interactive engagement and problem-solving skills domain. The interest and feedback domain had lower mean values highlighting areas for improvement. The qualitative phase expanded on how students' understanding was enhanced, and their interest sustained through KHA. Pedagogical implications for active learning through technology are discussed.

KEYWORDS

Active learning; Technology-enabled active learning (TEAL); Virtual Reality (VR); Augmented Reality (AR)

Introduction

In Malaysia, it has been reported that a high percentage of HE students were very dependent on lecture notes and lacking in self-regulating study skills (Amir & Jelas, 2011). Due to the exam-oriented education system, most of the students are passive learners and tend to memorise facts (Yee et al., 2015), disadvantaging them from developing higher order thinking skills (Abdullah et al., 2019). Furthermore, lecturers were found to be either teacher-centred (Jelas et al., 2016) or subject-matter-centred (Han & Yusof, 2019).

This is where technology plays a promising role in *active learning*; where students participate or interact with the learning process (Bonwell & Sutherland, 1996), as opposed to taking in information passively. Formats of active learning include heuristics learning, problem-based learning, experiential learning, as well as group discussions and debate (Lee et al., 2018). Nonetheless, active learning is often confined to the level of instructional formats that integrate discussions and presentations. Roberts (2017) cautioned against overemphasising format in active learning, at the expense of learning quality and its content. Understandably, Matsushita calls for deep active learning (2017), which shifts the

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focus from formats – to the quality and content of learning; that is deep understanding and engagement in higher analytic skills (i.e. reasoning and application).

The use of technology has fundamentally changed the pedagogical practices of the classroom. Technology-Enabled Active Learning (TEAL), which was initiated at the Massachusetts Institute of Technology (MIT) in 2001, featured media-rich software for simulation and visualisation to facilitate students' active learning (Shieh, 2012), allowing students to understand complex concepts and phenomena. Several studies have examined the impact of TEAL on university students in fields such as Physics (Shieh, 2012), and practical training in vocational education (Hassan et al., 2015). These studies found that students achieved higher learning gains in comparison to those studying in traditional classrooms (i.e. Parishan et al., 2011; Shieh, 2012) in that students' comprehension and retention of concepts was significantly greater (Liu et al., 2020) due to the use of spatial and dynamic images (Dori & Belcher, 2005). This encourages a student-centred active learning experience (Ellis & Bliuc, 2019), resulting in higher order thinking skills (Shi et al., 2019). Given the many benefits of TEAL, a greater understanding with newer technologies such as augmented reality (AR)/virtual reality (VR) thus becomes necessary.

Literature review

The potential of AR in education is attributable to its characteristics. AR is 'defined as the technology that overlays virtual objects in the real world' (Akçayır & Akçayır, 2017, p. 1). Augmented reality (AR) technology facilitates the understanding of concepts since it supplements the user's sensory perception of the real world and offers a new form of interactivity between real and virtual worlds (Han et al., 2019).

Several studies suggest that AR technology is potentially useful in reducing students' cognitive load when engaging in complex concepts such as geometry (Ibáñez et al., 2020) and problems of 3D visualisation (Moorhouse et al., 2019). The technology of augmented reality (AR) might also facilitate the understanding of scientific concepts since it supplements the user's sensory perception of the real world by adding computer-generated content to the user's environment (Garzón & Acevedo, 2019).

Virtual reality (VR) is defined as 'an artificial environment that is created with software and presented to the user in such a way that the user suspends belief and accepts it as a real environment' (Joiner, 2018, p. 112). VR is an immersive, multi-sensory experience and 'Virtual reality refers to immersive, interactive, multi-sensory, viewer-centered, 3D computer generated environments and the combination of technologies required building environments' (as cited in Cipresso et al., 2018, p. 2).

When used in an education context, students are not limited by time or space when immersed in the VR learning flow (Chang et al., 2020), thus providing a highly interactive and simulated environment through visual representations. Hence, VR has become a useful technology in education, increasing motivation (Tilhou et al., 2020), analytical skills (Radianti et al., 2020) and self-efficacy (Chen & Hsu, 2020), since engagement is enhanced through meaningful visualisations (Shi et al., 2019).

AR and VR technologies allow learners the freedom to actively experience digital content and integrate new information into their existing knowledge, thus engaging on an individualised path of discovery (Kim et al., 2020). This ability to grasp complex

concepts is particularly relevant for connecting and engaging with history and cultural heritage and promoting active learning.

Although there have been many studies on TEAL, there is a paucity of studies that combine both AR and VR technologies in examining students' experiences of learning about cultural heritage in the Malaysian context. Thus, the following research questions are proposed:

(1) How do students' experience learning about culture and heritage through the hybrid Augmented reality (AR) and Virtual Reality (VR), Kuching Heritage app?
(2) What is the relationship between the four domains of TEAL (interest, feedback, interactive engagement and problem-solving skills)?

Method

Data collection

Context

Swinburne University of Technology Sarawak hosted Good Design Week (GDW) in 2019. This academic gathering brought together applied design research, practice, governance and scholarship to examine good design for culture, heritage, eco-tourism and creative economy. GDW 2019 was attended by both students and staff from both Curtin University, Australia and Swinburne University of Technology, and experts from design firms. We utilised this platform to investigate whether the integration of the Kuching Heritage App (KHA) could be beneficial for active learning of cultural heritage for HE students.

Participants

Student participants for the study were invited from the attendees of GDW 2019, making this convenience and purposive sampling (Etikan et al., 2016). A total of 59 questionnaires were successfully completed. The majority of student participants were undergraduates (61.0%), followed by postgraduates (27.1%) and pre-university students (11.9%) from the universities above. The students tended to use smartphone devices (Very Often 25.4%; Always 72.9%, Sometimes 1.7%) over tablets (Very Often 5.1%; Always 22.0%; Sometimes 20.3%). The student participants also reported that they are more familiar with VR (Moderately familiar 42.4%; Extremely familiar 15.3%) compared to AR (Moderately familiar 28.8%; Extremely familiar 13.6%) technology.

Instrument

To gather information on students' perceptions of active learning with KHA, the validated TEAL Inventory (Shroff et al., 2019) was utilised. The Cronbach's coefficient alpha ranged from 0.83 to 0.88. The TEAL inventory used a Five-Point-Likert scale ranging from 'fully disagree' to 'fully agree'. Follow-up semi-structured interviews were also utilised, to collect data emerging from the TEAL inventory.

The Kuching Heritage App

The KHA was developed through a software called Unity. **360°** images of the heritage sites were captured and used for the VR feature, while 3-dimensional models and image markers were designed specifically for the AR. The AR/VR activity goal was to facilitate students' learning about two cultural heritage sites in Kuching, remotely. Participants were initially asked to execute the app through mobile devices, provided by the researchers. In the main menu, participants were presented with two options: (1) to execute the AR mode, and (2) to execute the VR mode. In the AR mode, participants held the mobile device and scanned the AR markers of the heritage buildings to view the content. The AR virtual models will then appear in the mobile device screen. Whereas in VR mode, participants utilised a VR headset in order to view the content projected through the mobile's stereoscopic view. The AR+VR experience showcased the Old Courthouse and the Square Tower. Through this app, users were able to experience Kuching's heritage building time-lapse from past to present, and attempt several problem-solving activities. Each participant had at least one session with an average of 15–20 minutes. The problem-solving activities involved navigating the virtual environment to learn about heritage sites (see Figure 1).

Procedure

After participants experienced the application, they were invited to complete the questionnaire in their own time. A separate time was also arranged for participants who consented to be interviewed. Participation for both phases of the study was voluntary and anonymous.

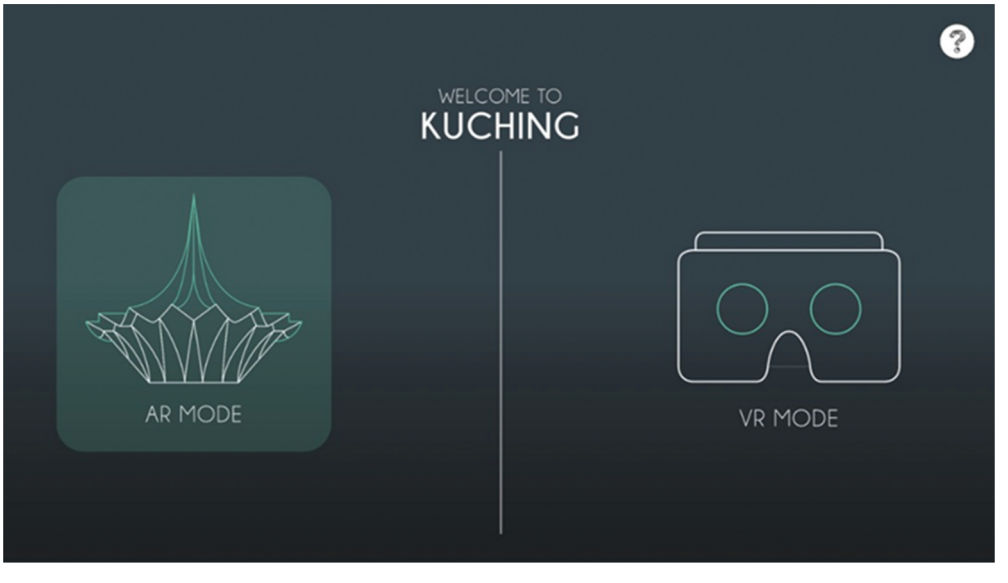

Figure 1. The Kuching Heritage App.

Data analysis

Data from the questionnaires were analysed using SPSS25.0. Two primary forms of statistical analysis were conducted: (i) descriptive statistics to present emerging trends and descriptions of the population and (ii) Spearman's correlation analysis to measure the strength of association between the TEAL domains; interactive engagement, interest, feedback and problem-solving skills. The qualitative data from semi-structured interviews were analysed second in the sequence to help explain, or elaborate on the quantitative results (Ivankova et al., 2006). Analysis of the qualitative phase was carried out inductively (Barbour, 2008) based on the data converged from student interviews and interview notes. The data helped build an account of the students' experience with KHA and which TEAL variables were pertinent in their experience.

Results

Overall, students responded positively to the TEAL questionnaire's four domains, as indicated by the high mean value (see Table 1). The interactive engagement domain ranked highest in terms of the average mean value (4.10), followed by problem-solving skills (3.98). Interest and feedback ranked third and fourth, with the average mean value of 3.92 and 3.86, respectively.

Two items in interactive engagement *('actively engage with the user-interface in a way that promotes dialogues'* and *'facilitated the exchange of information by engaging with content presented in diverse formats')* and an item in the feedback domain *('enabled me to receive responses that allow further understanding'*) obtained the highest mean value of 4.17 and 4.11 respectively. Nonetheless, the majority of items in feedback received relatively lower scores across four domains. The items: *'receive input, so that I was able to keep track of my own performance*', and *'receive prompt feedback, so that I was aware of*

Table 1. Technology-Enabled active learning through Kuching Heritage App.

Domain				Percentage (%)				
	Mean	SD	SD	D	N	A	SA
Interactive Engagement								
9 Actively engage with the user-interface in a way that promotes dialogues	**4.17**	.834	1.7	3.4	6.7	52.5	35.6
17 Facilitated the exchange of information by engaging with content presented in diverse formats	**4.17**	.813	1.7	0.0	15.3	45.8	37.3
Problem Solving Skills								
2 Methodically generate ideas by contributing information from multiple viewpoints	4.03	.787	1.7	1.7	13.6	57.6	25.4
18 Allowed me to define the problem systematically by viewing it from different angles in an effort to find possible solutions	4.02	.841	1.7	0.0	23.7	44.1	30.5
Interest								
3 Engage in thought-provoking dialogue with points of view that challenged my perspectives	3.92	.816	1.7	1.7	22.0	52.5	22.0
11 Explore various options when navigating the user interface	4.03	.890	1.7	3.4	16.9	45.8	32.2
Feedback								
16 Receive prompt feedback, so that I was aware of my own progression towards mastery of my skills	3.75	.902	1.7	3.4	35.6	37.3	22.0
20 Enabled me to receive responses that allow further understanding	**4.15**	.784	1.7	0.0	13.6	50.8	33.9

Note: Not all items are presented in the table.

my own progress towards mastery of my skills' received a mean value of 3.73 and 3.75 respectively. This finding highlighted the need to provide better feedback and progress monitoring.

Overall, the correlations between all TEAL domains are positive and significant. The highest correlation identified was between interactive engagement and feedback (r = .814**). This was anticipated as immediate feedback through the app further enhances engagement as it allows further understanding. The second highest correlation occurred between interest and interactive engagement (r = .791**). The lowest correlation is identified between interactive engagement and problem-solving skills (r = .798**).

The emerging findings from the questionnaire, particularly on feedback and interactive engagement formed the basis of the semi-structured interview guide in the following phase. Five students participated in the interview. The qualitative data findings affirmed the capacity of the KHA to induce key characteristics of active learning. In the qualitative findings, students explained how the use of KHA stimulated their attention and increased engagement with content. Students reported active involvement in the learning, rather than merely duplicating or regurgitating information, or what the students termed, the '*traditional way*' of learning about history.

The app provided authentic, interactive and meaningful experiences, hinting on characteristics and substantial elevations of active learning. All the respondents commented that KHA afforded the opportunity to not only learn in an active environment, but also made the subject matter more interesting. This is evidenced by students' positive responses and attitude towards KHA since they considered it *'effective, interesting* and *fun'* to learn about cultural heritage.

> *Using the KHA was an interesting experience. It is a different way of learning things, and the interactivity makes it less boring. I was immersed in the process, even though I wasn't actually there*. (XiuWen, p. 19)

> *It was interesting and effective in helping me understand the history of the two heritage sites. I was able to explore, and there was hands-on problem-solving*. (Natalie, p. 19)

> *The KHA was also fun; because you are looking at something that isn't possible if you are not physically there – I can experience it as if I'm really there* (Sam, p. 20).

Consequently, the students seemed to be fully focused on the tasks and were engaged in the virtual environment. In the interviews, students also reported a preference for technology instead of the traditional book-based education:

> *It was more exciting and effective compared to the traditional way. I was more involved, and I can manage based on my own pace . . . going back to points I don't understand and trying it many times. I was experiencing everything, instead of just digesting and listening in a typical lecture* (Natalie, p. 19).

The KHA also prompted curiosity for other students who reported managing their own learning at their own pace. This self-regulated trait was evidenced below:

> *The app made me want to explore the sites, not just from an engineering perspective. I became very curious. I actually wanted to go into the building – see what's inside. The past to present part . . . I was navigating that experience myself, especially the pace of the exploration. To me, when the learning is more detailed and more interactive – it becomes interesting* (Sam, p. 20).

What also emerged from the interview data was evidence of active learning in which students were making connections and critically thinking about the applicability of such technology in their own fields.

> *The app did create awareness about heritage sites. I was thinking – how did it work, about the structure of the sites and the different markers and points. If they had similar technology for engineering students, it would certainly be very helpful in understanding structural aspects of construction and buildings*. (Kelvin, p. 20)

> *The same principle can be done for dental surgery. That would be very helpful instead of textbook*s (XiuWen, p. 19).

Nonetheless, the interview findings also revealed that certain areas could be further improved.

> *For me, it was a good platform but it needed more development. I think the content would need to be more challenging, especially for different age groups. . .and the visuals could be better too* (Kelvin, p. 20).

> *The learning was broken into manageable points. So I was in control. However, I wasn't so sure of the progress I made* (XiuWen, p. 19).

Overall, students' comments shed light and complemented their answers in the questionnaires. Such feedback provided insights into active learning in which students reported higher order analytic skills such as reasoning and application.

Discussion

How KHA enabled active learning of culture and heritage

The findings from this pilot study are an example of how an immersive interface can enhance learning because they provide multiple perspectives (exocentric and egocentric) of a phenomenon. Like the study by Roberts (2017), the KHA images reduced students' cognitive overloading and instead, leveraged on their visual processing capacities. This allowed learners to engage dynamically with content. This resonates with Dede (2009), who maintains the value of using these technologies to generate active learning behaviours.

Students reported higher engagement levels suggesting that the learning experience captured their interest, created curiosity and helped them focus on the key information of the learning content. This result supports previous studies reporting the positive impact of AR applications on the attention dimension (Dunn & Kennedy, 2019, p. 104) while allowing learners to participate in and take control of their own learning processes (Marton, 2018).

Visualisations, particularly through the time-lapse, provided opportunities for pushing the boundaries in interacting with the physical environment. Cochrane and Farley (2017) maintain this benefit of transporting users to virtual learning spaces beyond the confines of their physical location for learners. That the consensus reported they would recommend the app to fellow students; citing the benefits of interactivity, visualisation, and immediate feedback, lend support to how education can leverage AR and VR's potential. The interactive virtual environments likely allowed students to actively control

the educational environment, giving them the feeling that they are present at a particular time in history. These findings echoed Korallo et al.'s (2012) assertion, in that virtual environments enhances students' understanding of history since there is access to realistic historical materials. Thus, this pilot study confirms AR and VR technology's pedagogical contributions for learning about cultural heritage as well as the advantages brought about by the use of KHA in active learning as postulated by Garzón et al. (2020).The KHA can be integrated as a pedagogical tool and embedded in the pedagogical approach.

The relationship between KHA and TEAL

The study uncovered students' experience with hybrid reality and identified interactive engagement and problem-solving skills domains were significantly impacted. The qualitative data further expanded on the mechanisms of the domains, revealing how students' understanding and knowledge was enhanced. The findings thus confirm that through TEAL, learners are transformed from 'being passive information receivers' to 'active knowledge explorers' (Mikropoulos & Natsis, 2011, p. 775) as evidenced by the excerpts: *'going back to points I don't understand and trying it many times*' and '*I was experiencing everything, instead of just listening in a typical lecture'*. This echoes Moorhouse et al. (2019) who maintain that effective use of technology can lead to the development of critical thinking skills (i.e. applicability to other disciplines). This finding also debunks the myth that Malaysian students are passive learners, rather than active contributors in knowledge construction (Zakaria et al., 2010) (Zakaria et al., 2010).

Like other studies (see Kazanidis et al., 2018), the technology promoted and enhanced critical thinking about history and cultural heritage. The more sophisticated pedagogical technologies of AR/VR were able to provide more optimal learning outcomes such as increased engagement, and rapid analytical skills. Furthermore, combining the hybrid app and active learning pedagogies has enriched student learning experiences (i.e. transferring the knowledge learned in a specific context to solve real-world problems in similar contexts) (Acosta et al., 2019).

Conclusion and implication

Overall, the findings of the study provided empirical evidence that KHA was a useful tool for active learning, has positive effects on student learning, thus affirming its pedagogic value. The findings also indicate that teaching practices combined with interactive technologies that foster agency effectively sustain active learning practices, and have great potential for other pedagogical activities. Thus, there is a need to leverage such technology to support active learning in HE. As the apparent limitation of the study is the small number of participants (questionnaire, $n = 59$; interview, $n = 5$) and the reliance on self-reports, future studies could include a larger number of participants from other universities, to capture a more diverse demographic from other fields or disciplines.

Disclosure statement

No potential conflict of interest was reported by the authors.

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References

Abdullah, H. S. B., Awang, M. M. B., & Ahmad, A. R. (2019, October 19). *Implementation of historical thinking skill among Malaysian students using History textbook: Concept, issues and challenges* [Paper presentation]. *The 2nd International Conference on Sustainable Development and Multiethnic Society*, Batam, Indonesia.

Acosta, J. L. B., Navarro, S. M. B., Gesa, R. F., & Kinshuk, K. (2019). Framework for designing motivational augmented reality applications in vocational education and training. *Australasian Journal of Educational Technology*, *35*(3), 102–117. https://doi.org/10.14742/ajet.4182

Akçayır, M., & Akçayır, G. (2017). Advantages and challenges associated with augmented reality for education: A systematic review of the literature. *Educational Research Review*, *20*, 1–11. http://www.sciencedirect.com/science/article/pii/S1747938X16300616

Amir, R., & Jelas, Z. M. (2011). A study of the learning styles of Malaysian students. *Asian Journal of University Education*, *7*(1), 85–96. https://education.uitm.edu.my/ajue/wp-content/uploads/2019/05/A-Study-of-the-Learning-Styles-of-Malaysian-Students.pdf

Barbour, R. S. (2008). *Introducing qualitative research: A student guide to the craft of doing qualitative research*. Sage.

Bonwell, C. C., & Sutherland, T. E. (1996). *Using active learning in college classes: A range of options for faculty*. Jossey-Bass.

Chang, S.-C., Hsu, T.-C., & Jong, M. S.-Y. (2020). Integration of the peer assessment approach with a virtual reality design system for learning earth science. *Computers & Education*, *146*, 103758. http://www.sciencedirect.com/science/article/pii/S0360131519303112

Chen, Y.-L., & Hsu, -C.-C. (2020). Self-regulated mobile game-based English learning in a virtual reality environment. *Computers & Education*, *154*, 103910. https://doi.org/10.1016/j.compedu.2020.103910

Cipresso, P., Giglioli, I. A. C., Raya, M. A., & Riva, G. (2018). The past, present, and future of virtual and augmented reality research: A network and cluster analysis of the literature. *Frontiers in Psychology*, *9*, 1–20. https://doi.org/10.3389/fpsyg.2018.02086

Cochrane, T., & Farley, H. (2017). Special issue on mobile AR & VR: Integrating SOTEL in learning design. *Australasian Journal of Educational Technology*, *33*(6), i–vi. https://doi.org/10.14742/ajet.4132

Dede, C. (2009). Immersive interfaces for engagement and learning. *science*, *323*(5910), 66–69. https://doi.org/10.1126/science.1167311

Dori, Y. J., & Belcher, J. (2005). How does technology-enabled active learning affect undergraduate students' understanding of electromagnetism concepts? *Journal of the Learning Sciences*, *14*(2), 243–279. https://doi.org/10.1207/s15327809jls1402_3

Dunn, T. J., & Kennedy, M. (2019). Technology enhanced learning in higher education; motivations, engagement and academic achievement. *Computers & Education*, *137*, 104–113. https://doi.org/10.1016/j.compedu.2019.04.004

Ellis, R. A., & Bliuc, A.-M. (2019). Exploring new elements of the student approaches to learning framework: The role of online learning technologies in student learning. *Active Learning in Higher Education*, *20*(1), 11–24. https://doi.org/10.1177/1469787417721384

Etikan, I., Musa, S. A., & Alkassim, R. S. (2016). Comparison of convenience sampling and purposive sampling. *American Journal of Theoretical and Applied Statistics*, *5*(1), 1–4. https://doi.org/10.11648/j.ajtas.20160501.11

Garzón, J., & Acevedo, J. (2019). Meta-analysis of the impact of Augmented Reality on students' learning gains. *Educational Research Review*, *27*, 244–260. http://www.sciencedirect.com/science/article/pii/S1747938X18301805

Garzón, J., Baldiris, S., Gutiérrez, J., & Pavón, J. (2020). How do pedagogical approaches affect the impact of augmented reality on education? A meta-analysis and research synthesis. *Educational Research Review*, *31*, 1–19. https://doi.org/10.1016/j.edurev.2020.100334

Han, D., Weber, J., Bastiaansen, M., Mitas, O., & Lub, X. (2019). Virtual and augmented reality technologies to enhance the visitor experience in cultural tourism. In M. C. Tom Dieck & T. Jung (Eds.), *Augmented reality and virtual reality* (pp. 113–128). Springer.

Han, L., & Yusof, M. A. M. (2019). Students' self-reflections of own participation in English language oral class. *LSP International Journal*, *6*(2), 79–92. https://doi.org/10.11113/lspi.v6n2.92

Hassan, N. F., Puteh, S., & Buhari, R. (2015). Student understanding through the application of technology enabled Active Learning in practical training. *Procedia-Social and Behavioral Sciences*, *204*, 318–325. https://doi.org/10.1016/j.sbspro.2015.08.158

Ibáñez, M. B., Uriarte Portillo, A., Zatarain Cabada, R., & Barrón, M. L. (2020). Impact of augmented reality technology on academic achievement and motivation of students from public and private Mexican schools. A case study in a middle-school geometry course. *Computers & Education*, *145*, 103734. http://www.sciencedirect.com/science/article/pii/S0360131519302878

Ivankova, N. V., Creswell, J. W., & Stick, S. L. (2006). Using mixed-methods sequential explanatory design: From theory to practice. *Field Methods*, *18*(1), 3–20. https://doi.org/10.1177/1525822X05282260

Jelas, Z. M., Azman, N., Zulnaidi, H., & Ahmad, N. A. (2016). Learning support and academic achievement among Malaysian adolescents: The mediating role of student engagement. *Learning Environments Research*, *19*(2), 221–240. https://doi.org/10.1007/s10984-015-9202-5

Joiner, I. A. (2018). Virtual reality and augmented reality: What is your reality? In I. A. Joiner (Ed.), *Emerging library technologies* (pp. 111–128). Chandos Publishing.

Kazanidis, I., Palaigeorgiou, G., Chintiadis, P., & Tsinakos, A. (2018). *A pilot evaluation of a virtual reality educational game for history learning*. Academic Conferences International Limited. https://search.proquest.com/conference-papers-proceedings/á-pilot-evaluation-virtual-reality-educational/docview/2154984770/se-2?accountid=14205

Kim, M. J., Lee, C.-K., & Preis, M. W. (2020). The impact of innovation and gratification on authentic experience, subjective well-being, and behavioral intention in tourism virtual reality: The moderating role of technology readiness. *Telematics and Informatics*, *49*, 1–16. http://www.sciencedirect.com/science/article/pii/S0736585320300083

Korallo, L., Foreman, N., Boyd-Davis, S., Moar, M., & Coulson, M. (2012). Do challenge, task experience or computer familiarity influence the learning of historical chronology from virtual environments

in 8–9 year old children? *Computers & Education*, *58*(4), 1106–1116. https://doi.org/10.1016/j.compedu.2011.12.011

Lee, D., Morrone, A. S., & Siering, G. (2018). From swimming pool to collaborative learning studio: Pedagogy, space, and technology in a large active learning classroom. *Educational Technology Research and Development*, *66*(1), 95–127. https://doi.org/10.1007/s11423-017-9550-1

Liu, Q., Geertshuis, S., & Grainger, R. (2020). Understanding academics' adoption of learning technologies: A systematic review. *Computers & Education*, *151*, 1–19. http://www.sciencedirect.com/science/article/pii/S0360131520300579

Marton, F. (2018). Towards a pedagogical theory of learning. In K. Matsushita (Ed.), *Deep active learning* (pp. 59–77). Springer.

Matsushita, K. (2017). *Deep active learning: Toward greater depth in university education*. Singapore: Springer.

Mikropoulos, T. A., & Natsis, A. (2011). Educational virtual environments: A ten-year review of empirical research (1999–2009). *Computers & Education*, *56*(3), 769–780. https://doi.org/10.1016/j.compedu.2010.10.020

Moorhouse, N., Jung, T., & Tom Dieck, M. C. (2019). Tourism marketers perspectives on enriching visitors city experience with augmented reality: An exploratory study. In M. Claudia tom Dieck & Timothy Jung. (Eds.), *Augmented reality and virtual reality* (pp. 129–144). Springer.

Parishan, N., Jafari, E. M., & Nosrat, F. (2011). The effect of Technology Enabled Active Learning (TEAL) method in Biology on the academic achievements of students. *Procedia - Social and Behavioral Sciences*, *28*, 542–546. http://www.sciencedirect.com/science/article/pii/S1877042811025432

Radianti, J., Majchrzak, T. A., Fromm, J., & Wohlgenannt, I. (2020). A systematic review of immersive virtual reality applications for higher education: Design elements, lessons learned, and research agenda. *Computers & Education*, *147*, 1–29. http://www.sciencedirect.com/science/article/pii/S0360131519303276

Roberts, D. (2017). Higher education lectures: From passive to active learning via imagery? *Active Learning in Higher Education*, *20*(1), 63–77. https://doi.org/10.1177/1469787417731198

Shi, Y., Yang, H., MacLeod, J., Zhang, J., & Yang, H. H. (2019). College students' cognitive learning outcomes in technology-enabled active learning environments: A meta-analysis of the empirical literature. *Journal of Educational Computing Research*, *58*(4), 791–817. https://doi.org/10.1177/0735633119881477

Shieh, R. S. (2012). The impact of Technology-Enabled Active Learning (TEAL) implementation on student learning and teachers' teaching in a high school context. *Computers & Education*, *59*(2), 206–214. https://doi.org/10.1016/j.compedu.2012.01.016

Shroff, R. H., Ting, F. S. T., & Lam, W. H. (2019). Development and validation of an instrument to measure students' perceptions of technology-enabled active learning. *Australasian Journal of Educational Technology*, *35*(4), 109–127. https://doi.org/10.14742/ajet.4472

Tilhou, R., Taylor, V., & Crompton, H. (2020). 3D Virtual Reality in K-12 education: A thematic systematic review. In S. Yu, M. Ally, & A. Tsinakos (Eds.), *Emerging technologies and pedagogies in the curriculum* (pp. 169–184). Springer.

Yee, M. H., Md Yunos, J., Hassan, R., Tee, T. K., Mohamad, M. M., & Othman, W. (2015). Disparity of learning styles and higher order thinking skills among technical students. *Procedia-Social and Behavioral Sciences*, *204*, 143–152. https://doi.org/10.1016/j.sbspro.2015.08.127

Zakaria, M. H., Watson, J., & Edwards, S. L. (2010). Investigating the use of Web 2.0 technology by Malaysian students. *Multicultural Education & Technology Journal*, *4*(1), 17–29. https://doi.org/10.1108/17504971011034700