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Indian and Australian University Students' Acceptance of Using Accessible, Web-Based, and Smartphone-Delivered Augmented Reality in Tertiary Learning: A Cross-Country Analysis

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Indian and Australian University Students' Acceptance of Using Accessible, Web-Based, and Smartphone-Delivered Augmented Reality in Tertiary Learning: A Cross-Country Analysis

Abstract

Accessible and equitable education is a national priority recently highlighted by the Indian and Australian Governments. New developments in web-based architecture allow augmented reality (AR) lessons to be delivered via smartphone. Although educational technology is commonplace in the Australian curriculum, it is unclear if Indian tertiary students would be welcoming towards web-based mobile learning due to a historically slower uptake and only recent availability of connected devices in their educational system. This study evaluated feedback after using a web-deployed AR smartphone-based application across both Australia (70 participants) and India (100 participants) to see if this technology can assist in capacity building on a global scale. From thematic analyses on the provided feedback, it was identified that Australian students were more focused on the benefits received from the educational technology. In contrast, Indian students were far less critical of the embedded lesson, and more interested in the prospect of introducing the specific technology into their curricula. The data suggests that a rollout of web-based mobile AR for learning in countries more digitally-native should likely prioritise the content within it. Alternatively, for countries recently-introduced to educational technology, such as India, a rollout should focus on embedding the technology itself first. Although there is a risk of learners being distracted by the technology, smartphone web-based AR presents an excellent option to equitably provide a modern, innovative intervention, regardless of wealth, location, or status.

Practitioner Notes

1. Accessible quality education is a growing priority highlighted by the United Nations, India, and Australian Governments
2. There is a growing availability of smartphones worldwide, and this technology can be used to introduce technology-enhanced learning to tertiary students.
3. The findings from our research suggest that the perceptions of students between Australia and India can be quite different in regard to technological interventions for learning.
4. Indian students are more focused on the technology itself, while Australian students are more focused on the learning contained within.
5. Smartphone technology provides an accessible means to bring technology-enhanced learning into the tertiary environment which is well-received by a variety of students

Keywords

equitable education, accessible education, digital divide, mobile learning, tertiary education

Authors

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Introduction

India's current 2020 National Education Policy advocates the beneficial role that technology can play in education across the whole of India (Government of India, 2020). Within this document, one key consideration is to ensure the equitable use of accessible technology to innovate and better teach health and clinical education. This means that technologies such as virtual and mixed reality, which have large entry costs and high-power computing requirements, are not likely suitable to accommodate these goals. However, the increasing connectivity of individual Indians, through smartphones, means that web-based augmented reality (AR) may be a technology that is accessible to most and can help advance this area of need.

With India rapidly catching-up to the rest of the world in regard to smartphone connectivity, now is the time to reset our approaches to learning and explore universal equitable solutions to mobilise innovative context appropriate solutions to ensure learners have the best quality of education (Gaol & Prasolova-Førland, 2022). Talan (2020) suggests that mobile learning should be associated with new learning approaches, but the type of mobile device is important. With the ubiquitous adoption of smartphones across both India and Australia, new approaches to learning are now possible. This study was guided by the research question, w*ith the recent widescale availability and accessibility of smartphones in India, would Indian students welcome the use of mobile-based augmented reality within their curricula?* To provide an answer, this study aims to evaluate feedback and compare perceptions towards using mobile-based learning technologies between an Indian cohort of tertiary learners and a more digitally experienced cohort of Australian tertiary learners.

Globalising Educational Technology Practices

The Australian education system may be ideally placed to provide evidence-based insights into interventions that can be considered for use within the Indian system (Freeman, 2017). As such, there are continued calls for better integration between the two countries (Sharma & Yarlagadda, 2018), and initiatives such as the Digital India program are working to rapidly close this divide (Government of India, 2019). Sitting as a current national goal, the Australian Government has identified a range of benefits in the provision of innovative educational services to the Indian economy (Varghese, 2018). Of particular international importance, however, are those interventions that can be highly accessible to all regardless of wealth, location or status, as this also aligns with the United Nations Sustainable Development Goal: Quality Education (United Nations, 2020).

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Australia already has a longstanding use of technology-enhanced learning. In 2015, Australia was one of the first countries in the world to have more computers than students in schools (Thomsom, 2015). However, at the same time, (in surveyed regions) only 26% of Indian schools had computers installed at all (Government of India, 2016), and India was falling behind the rest of the world with technology-enhanced learning (Elangovan et al., 2021; Government of India, 2018; India Cellular & Electronics Association, 2020). This was exasperated by the fact that Indian educators were left largely untrained in regards to educational technology, meaning that simply increasing procurement of devices would not be enough (Central Square Foundation, 2015). Nowadays, although the update has been comparably slower, the reliance on computer-assisted learning in India is growing. In 2021 only 39% of schools used computers (with only 22% have access to the internet), meaning there has been an rise in the number of individuals connected (Ministry of Education, 2021). In 2015, only 20% of Indians had smartphones (Sun, 2021), whereas nowadays over 500 million people in India are now online, with over three Indians discovering the internet every second, mostly using smartphones (techARC, 2020).

Maximising the Benefits for the Smartphone-Connected Generation of Learners

With this new influx of smartphone availability for Indian learners, there is benefit in identifying ways to best use this for educational purposes. Of particular interest is AR, which has demonstrated great benefits for learning (Wu et al., 2013). With the rise of educational technology (Cowling et al. 2022), considerations need to be made for both the appropriateness of the intervention for the audience, as well as ensuring that it enhances learning in all contexts. However, some success has been found through the use of smartphones for interactive educational purposes. These purposes include activities such as live polling or to collect audience responses, which are becoming commonplace in educational settings (Phelps & Moro, 2022). In addition, through using the camera attached, AR provides a view of the surrounding area, and overlays a digital image onto it. This practice has been increasingly utilised in higher education (Moro et al., 2021), providing an interactive and engaging environment. Although the use of AR is increasing in Western tertiary institutions, there have been historical barriers in the use of this technology in Indian classrooms, as AR required expensive tablets or modern computers and cameras to run in a class (Moro et al., 2023). However, modern mobile AR is more accessible than ever, with the increasing computing power of entry-level smartphones (Birt et al., 2018; Moro et al., 2021), and their increasingly high-quality cameras, have the potential to visualise 3-dimensional (3D) models and animations in real-time. This means that computer-aided learning is increasingly available to all, regardless of wealth, location, or status (Jones et al., 2022; Wu et al., 2013).

In courses such as health sciences and medicine, body representations in 3D, and visualising movements, are of key importance to learning certain concepts. This is not possible through printed 2-dimensional (2D) lecture notes, and genuine 3D representations cannot be effectively represented in slide presentations or traditional lecture-based instructions (Fombona-Pascual et al., 2022). Face-to-face workshops, laboratories, and practical sessions can bridge this gap, but these usually sit as supervised sessions, with little opportunity for students to revise and learn outside of formally scheduled classes (Moro et al., 2021). Teaching through smartphones, in particular, using AR applications that can represent both 3D models as well as animations and movements of human body systems, could go a long way to enhance comprehension and address sustainable deployment (McLean et al., 2022; Moro et al., 2021). AR combines real and virtual objects, real-time interaction, and accurate registration of virtual and real environments in 3D (Azuma, 1997; Chang et al., 2013; Christopoulos et al., 2022). The overlaid information can be seamless, altering one's ongoing perception of the space including multiple sensory modalities (Billinghurst et al., 2015; Bimber & Raskar, 2015; Carmigniani et al., 2011). As such, AR can allow for spatial structures and connections to be made that can assist with spatial learning outcomes, and represent animations (e.g., the heart beating or an arm moving), in a way that is not possible when using traditional presentations such as slideshows or 2D printed resources (Finch et al., 2022).

Methods

Study Design

A mixed-methods approach was adopted for the study (Creswell & Plano Clark, 2017). Phase 1 of this approach included the collection of quantitative data via the survey questionnaire. The survey questionnaire examined two questions: *Participant experiences and perceptions of technology-enhanced learning* and *participant perceptions of augmented reality animations.* This survey consisted of 14 Likert-style questions, drawn from various other studies with the outcome to test student perceptions of AR (Bhagat et al., 2021; Bogomolova et al., 2020; Majid et al., 2015; Moro et al., 2021; Salem et al., 2020; Sarkar & Pillai, 2019). Examples of questions included: *Technology-enhanced learning is used well for effective teaching at my university; The AR animation helped me learn the content,* and *I found using the QR code to open the AR application was simple.* Phase 2 of this approach gathered qualitative data in the form of learner written reflection. The qualitative responses were provided in response to the open-ended question: *Please provide a few comments or thoughts regarding the use of the AR animation for learning.*

Participants and Recruitment

Students enrolled within Australian and Indian universities, in a clinical health science or medicine degree from all age groups, were eligible to participate in this mixed-methods study. Participants were recruited by advertisement slides presented during lectures, by the verbal offering of educators, or through bulk-email invitations to entire cohorts. A total of 170 volunteered to participate in this study (Australia group, n = 70, and India group, n = 100) and completed an informed consent form before viewing the handout and AR animation of isotonic arm contraction. All participants completed Phase 1 of this approach. No personally identifying information was collected, and all responses were recorded anonymously via Qualtrics XM. Participants' responses to each Likert style question, as well as any written comments, were anonymously paired.

Lesson Creation: Health Science, Medicine Physiology, and Anatomy

A PDF handout was provided to participants which contained written material on arm muscle contractions. In particular, this PDF explained isotonic contractions, including concentric and eccentric, along with a 2D illustration of a person lifting a weight. This lesson content was developed by physiology experts and checked by three separate educators prior to formal compiling into a PDF. At the bottom of the page, the text invited the reader to take out their smartphone and scan a QR code to access the website, which showed the muscle contracting in real-time through AR. Another link was further provided on the sheet to the Qualtrics link containing the survey.

Development of the Application

A 3D model of the arm was created by the authors (Figure 1) and checked for anatomical correctness by a panel of two anatomical lecturers and clinical doctors. The app was created using the Unity (2020 LTS, Unity Technologies, San Francisco, US) game engine and is available for access via a website. Links were available for both WebXR (Android-based devices) and Web AR (iPhones) versions. The app was marker-less and did not require installation on the user's device (running purely over the website). Once the app detected the ground through the device's camera, the 3D model of the arm was presented on the screen, and the animation started, which showed the muscle moving the arm up and down. A pinch-command was available for zooming in and out of the model, and by tapping and swiping the model could be rotated.

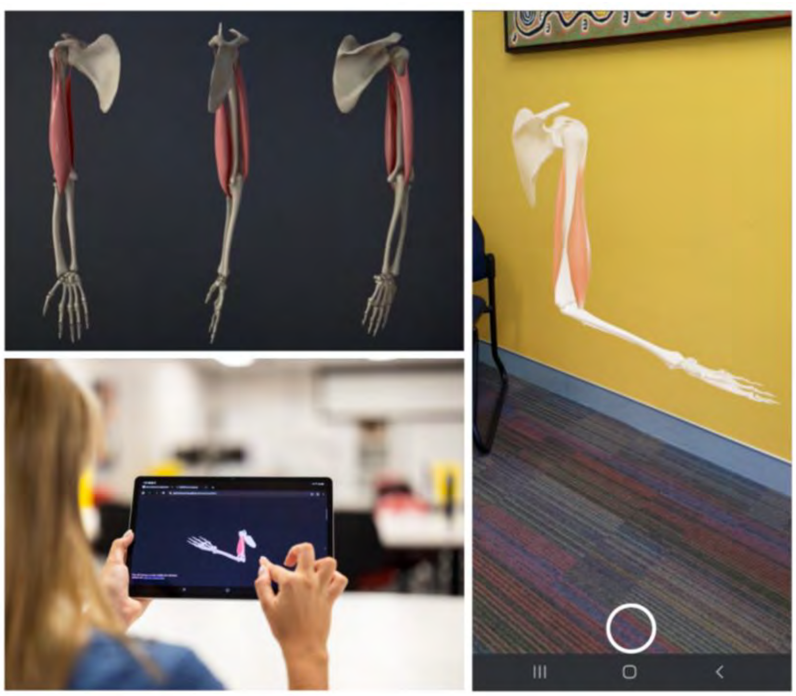

Figure 1:
Example of the 3D arm model used to animate muscle contraction (top left), a user engaging with the application (bottom left) and a screenshot of the final AR animation situated in the user's environment via the smartphone's screen (right).

Reliability and Validity

To validate the Phase 1 Likert scale survey questions employed throughout the study, a committee of five academics with experience teaching first-year health science and medical students was established. This expert committee evaluated the survey and established the face-validity of the questions (Drost, 2011). Each item was assessed for clarity, relevance, format, simplicity, grammatical construction, and comprehensibility. There was no training required for participants who completed the survey, as it was deemed to be relatively straightforward and uncomplicated. No participants presented any queries regarding survey questions after they had commenced the study. The results from the Likert Scale survey questions were assessed for reliability using SPSS v26 (IBM SPSS Statistics). As the identified variable was solely location of study, a unidimensional study would be appropriate, and all items (14 questions) were deemed to have good internal consistency based on the Cronbach Alpha value ($\alpha = .834$). However, due to the restrictions surrounding the Cronbach Alpha (Sijtsma, 2009), as an alternative assessment, an exploratory factor analysis was performed using varimax rotation and principal component analysis. There was significance of the correlation matrix through Bartlett's Test of Sphericity ($p < .001$), indicating suitability for factor analysis and the Kaiser-Meyer-Olkin measure of sampling adequacy was .820.

Data Analysis

For assessment of Phase 2 qualitative written responses, the Braun and Clarke (2006) six-phase qualitative analysis framework was applied to identify and assess themes emerging from each participant's written responses. This thematic analysis was completed manually by two independent authors (first and third named authors), followed by a meeting to settle and discuss any disputes appearing. A third author (last named author) had been made available to settle disputes. However, in all cases, disagreements were minor (with a high interrater reliability) and referral to the third author was not required. For assessment of Phase 1 Likert-scale data, participant responses were rated using a five-point scale (1=strongly disagree to 5=strongly agree), where higher scores indicated a positive perception about the learning mode. Using SPSS v26 an unpaired two-tailed Student's *t*-test was performed, with $p < .05$ being considered statistically significant. This assessment was used to evaluate perceptions from using the AR animation application between participants in Australia and India. The results were presented into graphs using Prism v9 (GraphPad Software).

Ethics

Ethical approval for the overall study was obtained from the (removed for anonymised manuscript) University Human Research Ethics Committee (removed for anonymised manuscript). Before commencement, participants read through an explanatory statement and provided informed consent to be part of the study. No personally identifying information was collected.

Results

A total of 170 participants' perceptions were collected and analysed from Australian (n = 70) and Indian (n = 100) cohorts, with 98 participants also providing written comments for thematic analysis (Australia group, n = 36 and India group, n = 58). Participants from the Australian cohort included students enrolled in a health science degree from an Australian tertiary institution. In India, participants were from two medical institutes who were enrolled in the second year of medical science courses. The mean age of the Australian participant group and the Indian participant group was 22.59 ± 0.67 and 21.21 ± 0.16, respectively (mean ± SEM). This study included 60 females (35%, Australia group, n = 46; India group n = 14), 109 males (64% Australia group, n = 23; India group n = 86) and one Australia participant who preferred not to report their gender (0.6%).

Participant Experiences and Perceptions of Technology-Enhanced Learning

Participants completed a six-item Likert scale survey regarding their overall perceptions of technology and AR at their respective institutions. The Australian group reported an increased implementation of technology and smartphones at their university (p < .001 and p < .05, respectively, Figure 2). Participants from the Indian group perceived AR to assist with learning and additionally reported using AR on a more frequent basis (p < .05 and p < .01, respectively).

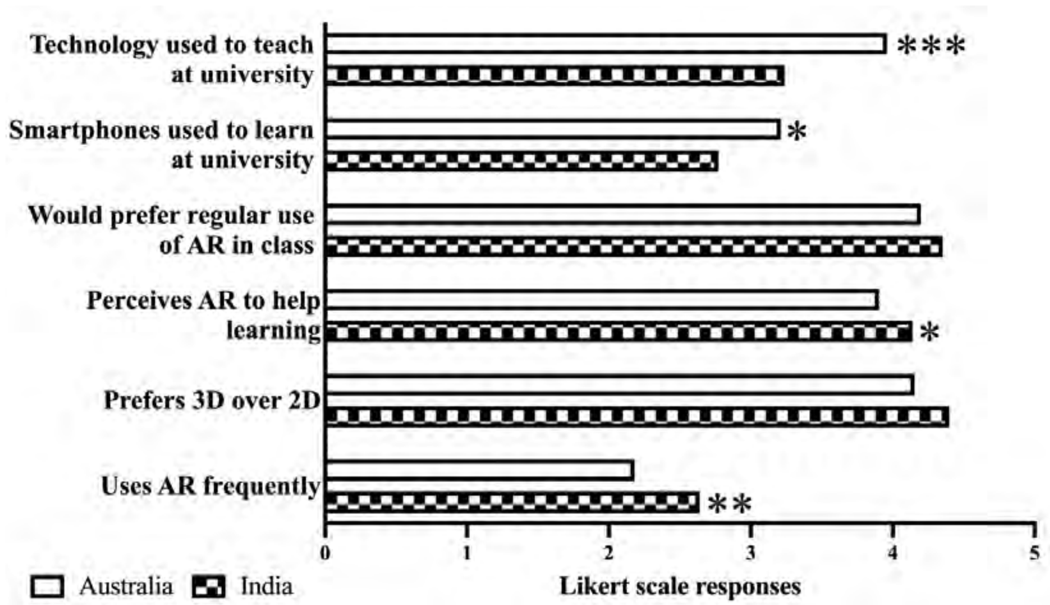

Figure 2:

*Likert scale responses of Australian and Indian participant perceptions on general technology and AR use at respective institution. Reported as mean ± SD. Responses marked from 1 (strongly disagree) to 5 (strongly agree). *p < .05. **p < .01, **p < .001.*

Participant Perceptions of Augmented Reality Animations

An eight-item Likert scale survey was administered to assess participant perceptions on AR animation use. Participants from the Australian cohort perceived the learning resource as accessible and favoured the appropriate motion and rendering of the animation more, compared to the Indian cohort (Figure 3). The Australian group reported the AR animation as easy to use and open when using the QR code (***p* < .01, and ***p* < .001, respectively). Additionally, the participants from this group better perceived the AR animation as realistic and highlighted the appropriate pace of the motion (**p* < .05 for all). Participants from the Indian group had high mean scores in categories of confidence in knowledge after viewing the AR animations and perceptions of the resource as being useful in a variety of settings. However, these findings were insignificant.

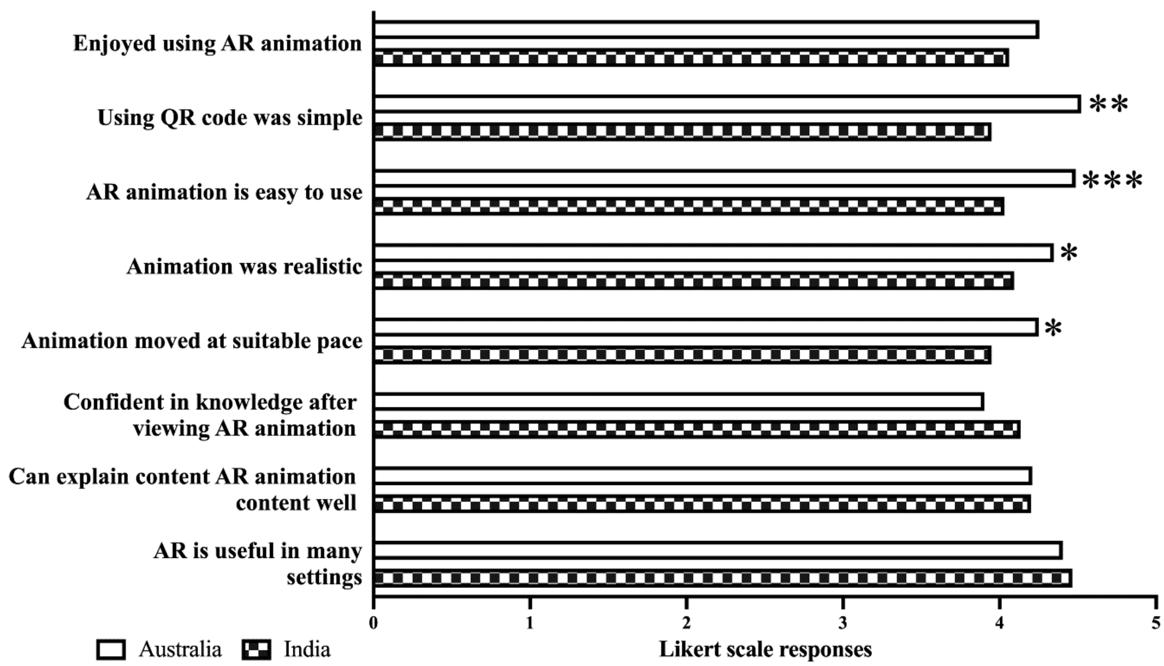

Figure 3:
*Likert scale responses of Australian and Indian participant perceptions on AR animations use. Reported as mean ± SD. Responses marked from 1 (strongly disagree) to 5 (strongly agree). *p < .05. **p < .01, **p < .001.*

Thematic Analysis

Theme 1: Augmented reality animations enhanced learning

Responses from both the Indian and Australian cohorts had a strong emphasis on AR animations being an effective learning tool. A total frequency of 51.35% and 77.59% of comments reported from the Australian group and Indian group, respectively, were directly categorised under this theme. In both cohorts, participants acknowledge the AR animations as a useful resource for learning, through its ability to assist in visualising a model and being a realistic animation (Table 1). However, some themes were inconsistent between cohorts, as the Australian group participants identified its capability for spatial-based learning. While the Indian group participants identified the resource's capability for enhancing the education system.

Table 1:
AR animations enhanced learning; subthemes and quotations

Cohort	Subthemes	Quotations
Australia	Helps visualise model	"The AR animation really helped me individually because I am a visual learner and being able to see and be in the 'moment' was crucial for me and helped me learn so effectively." (P13).
		"I think it would be a great tool for visual learners as you can see the planes of motion the arm moves through which would make it easier to understand rather than seeing a 2D drawing on a piece of paper" (P23).
		"As a visual learner myself, I was able to engage in the content and understand better than viewing it via 2D models." (P19).
	Realistic	"Helped make the learning realistic and easy to understand." (P6).
		"It's very realistic in the way that the movement of the AR animation mimics the body's movement." (P26).
		"AR animation can assist in learning extensively given that the body is 3 dimensional and the motions make so much more sense and are more realistic when viewed in AR and technology." (AuP29).
	Helps in spatial learning	"It was useful to see the movement of the arm rather than just looking at a static 2D object on the handout" (P2).
		"I can see its benefit for understanding more complex movements" (P3).
		"The animation was helpful to see movement of the arm and the muscles & bones involved" (P24).
India	Helps visualise model	"Visualizing the information along with relatable contexts can help students having a more elaborated knowledge." (P10)
		"AR in education helps students achieve better results through visualization and full immersion in the subject matter. So, instead of reading theory about something, students can see it with their own eyes, in action." (P18)
		"Visualization is like a superpower, which helps us to create a parallel world in understanding the things effectively. Developing this superpower as early as possible would definitely makes an individual to a next level of confidence in his life." (P51)

	Realistic	"AR animation gives a realistic view which helps in learning every aspect" (P18) "When information and concepts are presented in a photorealistic or diagrammatic manner via a visual medium, the human mind more comfortable grasps the given concepts and information to enhance learning." (P20) "The animation was very realistic and definitely helped me in understanding the different contractions of the different muscles in the arm. It can be a very efficient way of learning human anatomy. Rendering such high-quality animations in real-time seems to be quite a difficult task and the fact that the app works so seamlessly is great." (P54)
	Could further enhance the education system	"Love to adapt to the new technology for a better future & also for future generation" (P1) "It's very effective technology for many fields like it can help for making a better education system in country." (P42). "In the Indian scenario, the inclusion of technology in education is quite limited, the inclusion of AR animation in education can help to take our education to the next level." (P53)

Theme 2: Augmented reality animations are simple and easy to use

Both cohorts submitted comments in relation to the simplicity of using the AR animations. A total of 24.32% of the Australian group participant comments and 3.45% of the Indian group participant comments reinforced this theme. Relatively few comments were provided by the Indian group in relation to this theme, thus, only one subtheme of non-complexity was seen in common between the two cohorts (Table 2). Australian participants also identified the AR animations to be easy to use, based on its accessibility.

Table 2:

AR animations are simple and easy to use; subthemes and quotations.

Cohort	Subthemes	Quotations
Australia	Non-complex	"It was easy to work through." (P11). "Super easy to use and would be beneficial in Health Science degrees." (P33).
	Accessible	"It's very realistic in the way that the movement of the AR animation mimics the body's movement." (P1). "Very Handy" (P17).
India	Non-complex	"In contrast to the traditional one-dimensional approach of presenting information, AR offers two-dimensional and 3-dimensional methods." (P7). "The AR animation was good and easy to understand." (P13).

Theme 3: Augmented reality animations are interesting and enjoyable

Participants from both groups valued the enjoyable and interesting qualities of the AR animation resource. Overall, 16.22% and 17.24% from the Australian and Indian groups, respectively, provided comments in relation to this theme. However, neither cohort included comments with common subthemes (Table 3). Participants from the Australian group recounted the enjoyment of the resource due to its visuals and the fun experience it provided. Comments from the participants from the Indian group revealed their enjoyability stemmed from the engaging nature of the resource, as well as providing its enjoyment as a rationale for further use in tertiary institutions to further enhance the student learning experience.

Table 3.
AR animations are interesting and enjoyable; subthemes and quotations.

Cohort	Subthemes	Quotations
Australia	Enjoyed visuals	"I enjoy using the AR because I am a very visual leaner" (P26).
		“It was really interesting to see the arm movement” (P36).
		“I really liked the visuals.” (P37).
	Fun Experience	“Easy and Fun to use.” (P19)
		“Love it!” (P17)
India	Engaging	“AR animation makes the topics more engaging and interesting” (P29)
		“It makes the topic more engaging and interesting to learn.” (P46)
	Enjoyable enough for further implementation	“This should be implemented in schools and universities to enhance the educational experience.” (P47)
		“To enhance the learning experience, this should be applied in schools and institutions.” (P48)

Theme 4: The augmented reality animation application needs improvements

Suggested amendments were the final theme seen across participant comments from both groups. It was found that 43.24% from the Australian group participants and 22.41% from the Indian group participants, reported some aspect of improving the AR animation resources. Participants from both cohorts highlighted the need for implementing labels and texts in the resource for clarity (Table 4). In addition, both cohorts provided constructive feedback of animation being unrealistic, contradicting previous comments of AR animation resources being realistic. Participants from the Australian cohort preferred two-dimensional (2D) resources, as opposed to the three-dimensional (3D) nature of the AR animation, a subtheme unique to this cohort. A distinct subtheme presented by participants from the Indian cohort identified the technical difficulties as an improvement needed.

Table 4:
The Augmented reality animation application needs improvements; subthemes and quotations.

Cohort	Subthemes	Quotations
Australia	Labels and text improvements	"It would've been more helpful had the 3D animation been labelled with the muscles/bones involved and provided some description or caption to support the animation." (P24).
		"Wondering if there should be voiceover and some words to describe what's going on?" (P34).
		"It would have been better to have some labels." (P36).
	Unrealistic animation	"Difficult to see changes in muscle shape and length during contraction." (P4)
		"Perhaps it might be helpful to increase the contraction and elongation of the muscles a little more as it isn't very obvious." (P9).
		"Could look a little bit more realistic" (P22).
	Prefers 2D over 3D	"For this simple movement I felt like the handout provided more information, which complimented the images" (AuP3).
		"A bit distracting, I prefer to learn via 2D images for anatomy." (P27).
		"AR is great but sometimes it's too complicated to set up and it ends up being more time saving to simply use 2D models" (P30).
India	Labels and text improvements	"Please label the body parts." (P19).
		"Adding extra data, e.g. a short bio of a person, fun facts, historical data about sites or events, visual 3D models, would give students a wider understanding of topics." (P16).
	Unrealistic animation	"Tricep Eccentric contraction was not clear in the animation." (P26).
		"The muscle contractions and relaxations can be better shown with much more clarity and recognition." (InP27).
	Technical difficulties	"There are some technical difficulties." (P33).
		"For some reason AR was not working." (P13).

Comparison between emerging themes: Australian and Indian participants

Ninety-eight participants provided written comments (Australia group, n = 36 and India group, n = 58). Both cohorts reported similar results, as the themes of (1) augmented reality animations enhanced learning, (2) augmented reality animations are simple, and easy to use, (3) augmented reality animations are interesting and enjoyable, and (4) augmented reality animation application needs improvements were observed (Figure 4). The frequency of comments between cohorts was generally varied, as shown in themes of enhanced learning, simple and easy to use and needs improvement. Nevertheless, for the theme of interesting and enjoyable, both groups reported similar views. Overall, thematic analysis results suggest participants in the Indian group favoured the AR animation for enhancing student learning with less critique on improvements in comparison to participants from the Australian group.

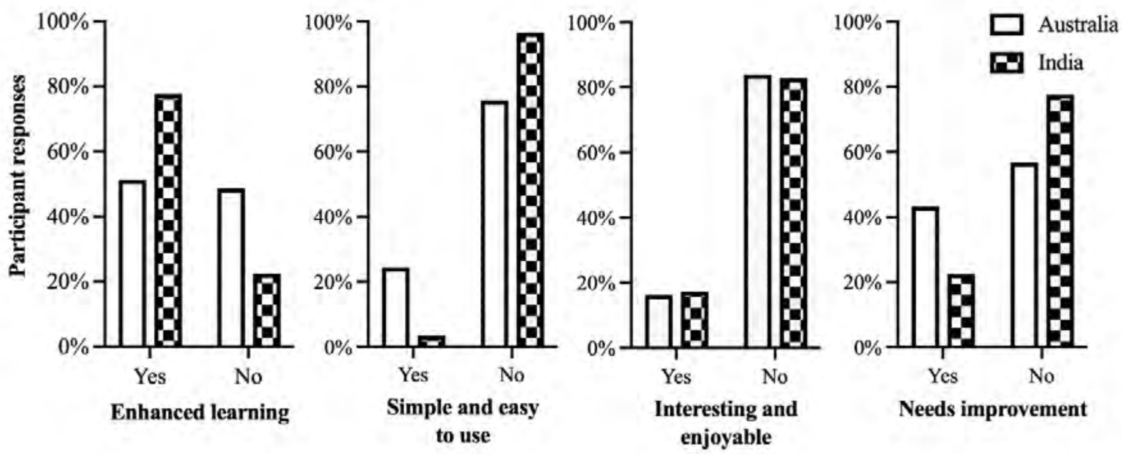

Figure 4:

Participants' overall comment perceptions of using AR animations from participants in the Australian and Indian cohorts. Reported as a percentage frequency of participants making a comment, either positive (yes) or negative (no), related to the theme.

Discussion

Breaking Down Barriers with Technology

Although there has been a growth in smartphone adoption in both India and Australia, access to context-appropriate solutions, where these devices can be used in learning, remains challenging. Many educators from multiple disciplines have conducted pilot studies on the applied use of AR using smartphone apps deployed through centralised stores or provisioned directly to phones (Birt et al., 2017) but the accessibility and deployment of these approaches are often complex within university governance, where learning management systems are the norm for educational deployment. New methods using augmented and virtual reality are emerging, improving accessibility and learning across a wide variety of fields, such as foreign language education (Lee, 2022), engineering (Papakostas et al., 2022), music education (Shahab et al., 2022) and geography (Garcia Estrada & Prasolova-Førland, 2022). These methods are more in line with university Learning Management System strategies and can be mapped more easily to course outline resources. Solutions using WebXR and WebAR are now available, but the engineering costs and deployment know-how is still in the early stages and a greater sharing of approaches is required.

Although mobile learning is not a new pedagogy, being over 20 years old (Naismith & Corlett, 2007), it has struggled to demonstrate practical, pedagogical achievements with some calling for the need for a new paradigm in mobile learning (Traxler, 2021, p. 11). Traxler (2021, p. 11) suggests that we must "start from scratch in understanding learning needs, cultural contexts and forces that shape [mobile learning] … given the ubiquity, pervasiveness and [universality] of mobile digital technologies.” In our results, we found that there were divides in the learning needs and cultural contexts of learners. Australian students focussed far more on learning improvements. Alternatively, Indian students focussed more on how the technology itself would benefit their learning. This may be explained by the Indian student’s higher personal use of technology, rather than specific use for learning. However, there was consensus across both groups that technology and smartphones should be used to teach at university and that methods used to access this e.g., the use of QR codes was considered helpful. This implies that the adoption of smartphone technology is reaching a point where innovative advanced methods using smartphones can be employed.

Although Australian students would be traditionally classed as more ‘digitally native’ (Prensky, 2001), there is certainly a growing digital diffusion of technology on a global scale (Doctor, 1991; Howland, 1998), where there is an increasing distribution of access to information technology between the “haves” and “have-not’s” (Van Dijk, 2006). Our finding, that Indian students are confident in maximising their use of a limited but growing mobile network technology, echoes the sentiment from regions, such as Africa (James, 2014; Onye & Du, 2016; Poushter & Oates, 2015), where citizens are working to bridge the ‘digital divide’ (Hohlfeld et al., 2008; Lebeničnik & Istenič Starčič, 2020).

Advanced Technology Enhanced Learning for All, Anywhere in the World

Kukulska-Hulme et al. (2021) highlighted in their Open University Innovation Report that AR enriched experiences engage learners and extend what is possible in education providing support in understanding concepts and contexts. In particular, it was noted that optimal learning moments are an emerging topic of importance, with attention and engagement of these moments enhanced through technology-enhanced learning, leading to more effective outcomes. Clinical and medical settings were identified as ideal contexts for the use of these enriched technologies and that these technologies are “within reach for learners with access to a suitable smartphone and a good Internet connection” (Kukulska-Hulme et al. (2021, p. 1). This is important as noted by the Quality Education UN Sustainable Goal (United Nations, 2020) that universal access is required to help mobilise and innovate education.

The identification that AR was accessible in our study demonstrated a key development in the technological field, that nowadays even basic smartphones now have the capacity to render 3D visualisations. This is important, as shown in our study that both sets of learners from India and Australia acknowledged the value of 3D visualisations over 2D. This reiterates the work of Stirling and Birt (2014) which highlights the importance of 3D representations for supporting cognitive load, building a mental picture and that 3D representations cannot be effectively represented in 2D presentations or traditional lecture-based instructions. The ability to have accessible access to 3D usually found in face-to-face workshops, laboratories, and practical sessions can now be delivered through a learner’s own smartphone, enhance learning and supporting revision and self-directed learning outside of formally scheduled classes (Moro et al., 2021).

This is continued with the value of the animation, as learners are more confident after viewing the AR animation, better able to explain the content with the AR animation and finding them easy to use. This reiterates the work of Berney and Bétrancourt (2016) that highlights the overall positive effect of animation when compared with static counterparts. The fact that smartphones can render real-time animations for 3D content supports the effectiveness in meeting the learners' expectations and the goals of universal access leading to education innovation. In addition, this research follows Moro et al. (2021) which identified that teaching through smartphones delivered animations and movements of human body systems, could go a long way to enhance comprehension and address sustainable deployment. Bringing technology-enhanced education to the Indian tertiary classroom also extends the developments which are currently growing across the country's high school environment, particularly in the field of Science Technology Engineering and Maths (Sarkar & Pillai, 2019).

Practical Implications for the Adoption of Augmented Reality

Lee et al. (2021)'s *State of XR & Immersive Learning Outlook Report* highlights the needs and opportunities presented by the evolving immersive reality technologies. However, as noted in the report, the barriers to adoption must be addressed to facilitate a general policy shift and integration of these emerging pedagogical methods into practice. These include access, affordability, infrastructure, interoperability, training, and content. Our current study is the first to investigate learner perceptions towards integrating web-based AR into the Indian tertiary education system. Regarding training, in the Indian context there is a growth of technology-enhanced education across the country's high school environment, particularly in the field of Science Technology Engineering and Maths (Sarkar & Pillai, 2019). This means that the next few years highlight an ideal time to investigate the benefits of introducing learning interventions at the tertiary level.

The positive feedback received in our study identifies that web-based AR certainly has the potential to work towards the National Education Priorities set in both India (Government of India, 2020) and Australia (Varghese, 2018), providing an affordable and accessible learning option that can also meet the needs of the United Nations Sustainable Development Goal for Quality Education (United Nations, 2020) and first two goals of the Lee et al. (2021) report. With learners now able to access these technologies through their smartphone and existing learning management systems, the issues around infrastructure can be resolved as phone-based app stores can be circumvented supporting administration and interoperability of the pedagogy. The generally favourable reception from both Indian and Australian students to the use of AR learning does show the potential for this technology to enhance the overall student experience.

Limitations and Future Directions

While the focus of our study was on the application of AR itself, learning was not required to be assessed. There might be some participant bias presented due to the relevance of the content to a health science degree, compared to participants enrolled in engineering. In addition, although international, this project was limited by the homogenous samples used across the three institutions. It was also not clear if the experience was the same across the wide variety of smartphone devices used, now if there was a different experience from those using either WebXR or WebAR. As this study focussed on participant perceptions, a great benefit would be found in future studies from the assessment of actual learning, which arises from the inclusion of mobile-based AR in class. Lastly, the authors acknowledged that although AR is one of the increasingly accessible technologies, there is an immense privilege associated with being able to access the technology in many regions. There is still a long way to go before this can be presented as an entirely equitable and sustainable technology for use in a teaching environment.

Conclusion

Traditionally digitally divided regions, such as India, have become more connected through technologies such as internet-connected smartphones. This presents an opportunity to utilise these devices to engage tertiary learners in technology-enhanced learning practices. In particular, this study has highlighted mobile-based AR as a highly viable, accessible, and well-received intervention to a tertiary curriculum. Nonetheless, some considerations should be made regarding its implementation across various countries. Australian students, quite possibly due to a longstanding use of technology and technology-enhanced learning, are more focused on the direct benefits received from these interventions compared to other learning modes. They are also quite critical of technology in general, and willing to provide feedback on how it could be adjusted to suit their individualised learning better. In contrast, Indian students are more likely to focus on the technology itself. Indian students were far less critical of the learning embedded within the website itself, and more interested in the prospect of this type of technology being introduced into their curricula. The data suggests that a rollout of web-based mobile AR for learning in countries more experienced with digital delivery should likely prioritise the content within in. Alternatively, for countries recently introduced to educational technology, such as India, a rollout should focus on embedding the technology itself first. Although there is an identified risk that any student, regardless of location or digital background, could become distracted by the technology during learning (Veer et al., 2022), smartphone web-based AR is an excellent option to embed modern, innovative education to all, regardless of wealth, location, or status.

Conflict of Interest

The author(s) disclose that they have no actual or perceived conflicts of interest. The authors disclose that they have not received any funding for this manuscript beyond resourcing for academic time at their respective university. The authors have produced this manuscript without any artificial intelligence support.

Contributions

Project Administration (CM, KKB, JB), Conceptualisation (CM, KKB), Data Curation (CM, KKB, VV, JB), Formal Analysis (CM, KKB, VV, JB), Investigation (CM, KKB, GCV, AD, VV), Methodology (CM, KKB, VV, JB), Creation of models (CM, KKB, GCV, AD), Resources (CM, KKB), Software (CM, KKB, GCV, AD), Supervision (CM, KKB), Validation (CM, KKB, JB), Visualization (CM, KKB, GCV, AD), Writing (CM, KKB, VV, JB), Review & Editing (CM, KKB, VV, JB).

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