Current State and General Perceptions of the Use of Extended Reality (XR) Technology at the University of Newcastle: Interviews and Surveys From Staff and Students

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Abstract
Extended reality (XR) technology is an emerging teaching tool within the higher education sector. Many institutions are currently running pilot projects, primarily assessing individual XR teaching tools typically being led by innovative/technology-driven teaching staff, which may introduce a self-selection bias and may not represent the general attitudes of the broader staff and student population. We applied a mixed-methods approach to gain insight into end-user acceptability, value areas, barriers, and opportunities for the adoption of XR in teaching at an Australian University. A university-wide online survey and targeted interview sessions with XR technology users show a general readiness for broad adoption of XR technologies in university education. Whilst existing XR teaching applications were described as “successful,” relatively few applications were sustainably integrated into the curriculum. Our data highlights the existing barriers for the successful transition from individual use-cases of XR tools to broader adoption across university institutions.

Keywords
extended reality (XR), virtual reality (VR), higher education, technology adoption, end user-acceptance

Introduction
“Virtual/extended reality is the future of teaching and learning.” This and similar statements are increasingly common in the higher education sector (Babich, 2019; Workman, 2018). Extended reality (XR) is an umbrella term used to describe any virtual- and real-world combined immersive environment allowing human and machine interactions, which contains categories such as virtual reality (VR), augmented reality (AR), and mixed reality (MR). The expanded use of digital technology in teaching, including XR applications, is being advocated by members of the technology industry and educators who are already using the technology (Hollander, 2018; Pomerantz, 2019; Wang et al., 2018).

VR creates a fully digital environment which is commonly delivered using a 360° range of view head mounted display (HMD) or headset, replacing the real world. This capability to simulate an immersive and interactive digital environment makes VR technology particularly suitable for teaching activities that are associated with high risk or high logistical costs and for visualization of abstract concepts including widely differing scales and to foster creativity and design (Bailenson, 2018; Boyles, 2017; Jensen & Konradsen, 2018; Makransky & Lilleholt, 2018; Proserpio & Gioia, 2007). Fully digital models, environments, or simulations can also be delivered using a 2D screen or PC, however these teaching applications are commonly not included in the term XR technology but are rather referred to as virtual learning experiences (VLEs). Whilst both types of applications can and are used for similar learning contexts, an important point of difference is the higher level of immersion and presence provided by the VR headset, which appears to have a

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positive outcome on the learning experience (Grassini et al., 2020; Lerner et al., 2020; Makransky et al., 2019; Makransky & Lilleholt, 2018; Ventura et al., 2019).

AR technology adds or overlays digital objects to a live view of a real environment, typically using a mobile device (Pokémon GO) or AR lenses, whilst MR combines elements from AR and VR describing the continuum of connection between digital objects with the real world (Berryman, 2012; Milgram & Kishino, 1994). Both categories can generate a mobile and context-specific learning experience, particularly effective for the delivery of targeted guidance and instructional teaching contexts (Dunleavy & Dede, 2014; Squire & Klopfer, 2007).

Many XR and VLE-based applications have been developed and implemented within the university sector, particularly in health-related schools and faculties (e.g., nursing & medical training; Barteit et al., 2021; Moro et al., 2017, 2020). These applications have mainly focused on XR-based simulations, procedural training, and anatomy teaching (Baker, 2017; Joda et al., 2019; Taylor et al., 2022). Other faculties and schools (e.g., engineering, creative industry, arts, and architecture) have integrated XR and VLEs for visualization, creation, and design (Kamińska et al., 2017; Lee et al., 2015; Wang et al., 2018).

As educators at an Australian university, we are very interested in the use of digital simulation technologies, particularly XR, and its potential to transform educational practices. Not being software designers ourselves however, we acknowledge that the use of XR raises many practical and conceptual questions for teaching staff. This issue is exacerbated by the variety of use cases, applications, technology categories, definitions, hardware solutions, and delivery modalities described online and in the literature.

A major question centers around how (and if) XR technologies can transition from an innovative teaching approach to an integrated, established, and reliable teaching resource in higher education. As with any new technology, XR uptake into the universities sector appears to follow the “innovation adoption lifecycle.” This sociological model, also termed the theory of Diffusion of Innovation, describes the steps involved in the transition of a new or innovative product, approach, or technology to become a well-accepted medium (Eveland, 1986; Rogers, 2003; Straub, 2009). To-date, the uptake of individual XR teaching applications have largely been driven by a small subset of committed and enthusiastic individuals within organizations, referred to as “innovators” in the innovation adoption lifecycle model. Innovators make up a small proportion of any given population (approximately 2.5%) and are the first individuals to adopt an innovation (Straub, 2009). They are generally excited about new possibilities, willing to devote time and often financial resources to the adoption of a new technology and have connections to the industry or scientific disciplines that relate to the new technology. It is important to recognize that innovators tend to be, by nature, risk-takers, and are aware that the adoption may or may not deliver the desired impact. Hence, they do not necessarily represent the views and attitudes of the general population. It remains unclear whether the approaches taken by innovators are scalable to broader institution-level uptake, implementation, and long-term diffusion and integration.

Debate remains around the effectiveness of XR educational tools in higher educational teaching (Taylor et al., 2022). Studies report benefits of VLEs (Canto et al., 2013; Nicholson et al., 2006), VR teaching applications (Falah et al., 2015; Legault et al., 2019), and AR tools (Shelton & Hedley, 2002; Yip et al., 2019). In contrast, other studies have failed to demonstrate statistical differences in teaching outcomes when directly comparing XR technology to established modalities in a range of teaching settings (Jensen & Konradsen, 2018; Kaplan et al., 2020; Moro et al., 2020; Huber et al., 2015; Wilson et al., 2018).

A potential reason for the varying accounts of effectiveness lies within the emerging field of designing and integrating XR technology for an educational context. Clear design guidelines are only just evolving (Gurevych et al., 2021; Radianti et al., 2020; Ziker et al., 2021). A point can be made that the assessment of XR is relevant only within its intended context, hence integrated within the curriculum. Like many educational innovations, XR technologies may benefit from an Educational Design Research approach, to bridge the existing gap between research and practice (McKenney & Reeves, 2014; Reeves & Lin, 2020). To this point Radianti et al. (2020) note in their systematic review the growing number of articles on VR applications, their domains and content areas, whilst highlighting limited evidence for their integrated utility in teaching as well a common failure to consider learning theories (Radianti et al., 2020).

Limitations for AR in practice center around practical usability, as learners and educators describe frustration and cognitive overload due to the unfamiliarity of the technology, technical errors, or reliability of internet connections (Dunleavy & Dede, 2014; Folkestad & O’shea, 2011; Saidin et al., 2015).

XR applications that demonstrate teaching benefits are typically connected to an underlying learning theory and leverage the advantages of the particular technology to address student interaction, manipulation of virtual components (e.g., scale, rotation, viewpoints), and teaching of complex concepts.

Particular value of XR has been reported for procedural, practical, or affective skills training in areas that are either high-cost, high-risk, or ethically difficult to address with traditional training modalities (Bouaicha et al., 2020; Garfeld Roberts et al., 2017; Jensen & Konradsen, 2018; Kaplan et al., 2020). Further, an important and consistently documented benefit of VLEs, VR, and AR technology in teaching is increased student motivation and engagement (Hodgson et al., 2019; Hsu et al., 2016; Jensen & Konradsen, 2018; Kustandi et al., 2020; Mikropoulos et al., 1998).
Despite a multitude of published use-cases of individual applications described in the literature and on University website, very little generalizable advice has been published that can be applied more broadly for educators interested in using the technology (Barteit et al., 2021; Bendeck Soto et al., 2020; Marks & Thomas, 2021). Sharing student and staff views on their experiences with VR has the potential to highlight unknown challenges and avenues, which can support decision making for educators considering the use of XR in their own courses (Baxter & Hainey, 2020). As such, we sought to assess the potential institutional and cultural enablers and barriers to the use of XR technology to support teaching at our institution, The University of Newcastle, Australia.

We performed a mixed-methods study with the aim to assess (i) how XR technology is currently used at The University of Newcastle (ii) as well as the end-user attitudes and acceptance toward the expansion of the technology into the teaching space. We were particularly interested in comparing attitudes between staff and students with limited experience using XR technology to staff currently using XR technology (i.e., innovators). Secondly, we sought to learn from innovators’ experiences and expertise with XR technology to identify existing barriers and enablers to inform the future scaling of XR technology across the institution. The results of this study will inform future implementation of XR technologies at our institution, and we believe will provide valuable insights for other higher education organizations in Australia and worldwide.

**Methods**

**Ethics Statement**

All research was reviewed and approved by The University of Newcastle Human Research Ethics Committee (Study reference: H-2019-00XX).

**Study Conception and Design**

In 2018, our university initiated a new educational design framework, which among other aspects sought to promote teaching innovation and expand practical support and resources. Within this context, the research group proposed the current study. The intent was to identify future avenues, opportunities, and barriers for XR technology, a university-wide assessment of current XR and VLE teaching applications was proposed to gather valuable information from those with experience in XR development, integration, and usage. Acknowledging that the views/experiences of those already using digital simulation technology may not be reflective of the broader university population, a university-wide survey of staff and student was conducted to assess the general attitudes, acceptance, and reservations toward XR technology.

A mixed-methods approach was undertaken, which included online surveys of the entire university population and targeted interviews with XR technology innovators. Both approaches sought to capture information on reservations toward, barriers, and general desire for VR and AR technology, as well as issues and concerns relating to practical implementation. Further, we specifically sought to identify value areas and approaches to support sustainable and scalable development, implementation, and future expansion of the technologies across the institution.

**Online Survey Development**

A new online survey was developed and distributed using SurveyMonkey (SurveyMonkey Inc., San Mateo, California, USA, www.surveymonkey.com) to capture personal attitudes and opinions toward XR technology from both the general staff and student population.

XR was defined as virtual-or augmented reality technologies. Questions for self-report were constructed using an iterative approach following a three-step process (defining constructs/content domains, item generation, and determining the format). The initial constructs and domains were identified based on scoping meetings, as mentioned above. Items were drafted and finalized using an iterative approach with feedback from all authors as well as a small sample of staff members including Heads of Schools and Faculties. Feedback was integrated to develop multiple choice questions using a 5-point Likert scale and multiple-choice questions. Survey questions are provided in Supplementary Materials.

**Survey Recruitment**

Survey responses were collected between 24th May and 24th September 2019. A web-link and QR code was circulated to provide access to the online survey via university-wide staff and student emails. In addition, flyers were posted across the University of Newcastle campus. Participation was voluntary, on an “opt-in” basis and included a $100 voucher prize draw as an incentive. Informed consent was given from all participants by ticking a box and continuing to the survey.

**Survey Analysis**

Staff and student survey responses were captured and analyzed separately. Quantitative data was analyzed question by question. Comparisons were made between groups determined a priori: (a) staff versus students, (b) teaching versus non-teaching staff, and (c) respondents with previous XR teaching experience versus no experience (both staff and students) using a nonparametric Mann Whitney test. Innovators were also encouraged to complete the online survey in addition to the interview. Alternatively, survey responses from innovator interviews were collected manually during the interviews and grouped within the population of staff with previous XR experience in teaching.
Interview Question Development

Formal, semi-structured interviews were conducted with identified innovators, using an open-ended question script querying views and experiences with any digital simulation technology, including VR, AR, and VLEs. Interview questions were drafted based on the priority areas identified in the initial scoping meeting, existing literature, and initial discussions and finalized with feedback from all co-investigators. Interview questions are provided in Supplemental Materials. Innovators were also encouraged to complete the online survey, as described above.

Interview Recruitment

Fourteen potential innovators were identified through an online search of university staff profiles and media coverage from the University communications office. Searches were conducted for relevant keywords including virtual reality, VR, virtual, augmented reality, AR, 360 video, teaching tool, application, digital simulation technology, avatar, and platform. All 14 innovators were approached and invited to participate individually via personalized emails. Written consent was obtained from all participants prior to commencement of the interview. One participant was subsequently excluded from further analysis, as their experience only included teaching about XR technology without practical application.

Interview Analysis

Interviews were audio-recorded and summarized non-verbatim by the interviewer. Digital transcripts were proof-read and approved by interviewees. Common themes were identified, which coincided with the themes applied in question development. These included: participant background; experience with XR technology; motivation for use of XR technology; XR application details, development and implementation; user feedback; and lessons learned. Transcripts were qualitatively assessed by two researchers independently, followed by a discussion relating to nodes using NVIVO Pro 12 software (version 12.4, 2020, QSR). Qualitative data was manually coded by topic areas and sorted into nodes including satisfaction, time commitment, continued use, barriers and difficulties, objectives, and requirements for broad usage of XR technology.

Results

Survey Participation

A total of 640 participants responded to the online survey. Of these, 224 (35%) were staff members, 368 (57.5%) students, and 48 (7.5%) both students and staff. Among staff respondents, 118 (50%) currently teaching at the university. Based on the 2019 university annual report, this corresponded to approximately 1% of the total enrolled student population (368 of 37,946) and approximately 7% of all staff (224 of 3,244 professional, academic and teacher, fixed term, and casual staff).

Responses were received from all University faculties (Health and Medicine 27.3%, Education and Arts 17.7%, Engineering and Built Environments 10.9%, Business and Law 5.5%, Science 8.8%, and English Language and Foundation Studies Center 2.5%), as well as non-Faculty university divisions (27%).

Current XR Teaching Applications at the University of Newcastle

A total of 11 XR teaching tools and 1 VLE were identified at The University of Newcastle through 2019 (Table 1; corresponding to 13 staff members). The first was used in 2011, whilst 7 of 12 were first utilized in 2018/2019. Virtual-reality (7) and augmented-reality (5) were the most commonly used technologies. Content duration for each application was relatively short with 6/12 applications lasting <10 minutes, 3 applications lasting 10 to 30 minutes, and 3 applications between 1 and 3 hours in length. Nine teaching tools were designed for (and only used in) one specific course. About 2 of the 12 tools identified potential for broad application across an entire degree.

Staff and Student Experience With XR Technology

Interestingly, 6 of 14 innovators specifically stated that they had limited exposure to XR technology prior to using their applications and self-identified as not being particularly skilled with the use of XR technology.

Within the broader university population, exposure to XR technology was also limited in general and particularly in an educational setting. While 70.6% of staff (n=161) reported some exposure to XR, total cumulative exposure was low (39.0% reported lifetime exposure <1 hour). Students had even less experience with the technology; 42.8% of students (n=140) had never used XR technology in any setting and among those who had previous XR experience 59.5% reported <1 hour of lifetime exposure.

Only 59 staff members (including innovators; 26.9%) and 36 students (11%) had used the technology in a university setting. Further, 73% of students (n=235) were “not so” or “not at all” aware of XR technology being utilized at the university. In contrast, approximately 45% (n=99) of staff respondents were “somewhat” aware of its current use, while 38% (n=83) were “not so” or “not at all” aware (the remaining 17% were “aware” or “very aware”).
Despite limited exposure and experience with XR technology, both staff and students were positive about its potential utility in education. The data shows no statistical difference between staff and student responses. Only 6.7% of staff (n = 13) and 20.4% of students (n = 61) agreed with the statement that “XR technology is a passing trend” (Figure 1a). In contrary, the technology was viewed as “likely” or “very likely” to become a standard tool in university environments (77.6% of staff (n = 148) and 66.2% of students (n = 186); Figure 1c) and a powerful tool that should be utilized in teaching (76.3% of staff (n = 148) and 64.8% of students (n = 186); Figure 1a). When asked about the future of XR specifically at The University of Newcastle, 62.8% of staff (n = 108) and 64.8% of students (n = 186) considered it “realistic” or “very realistic” that the university will develop a sustainable and suitable implementation framework within the next 5 years (Figure 1c).

Whilst students were relatively neutral on whether the inclusion of XR technology would influence their course selection (weighted average = 3.35; 1 = very unlikely, 5 = very likely), students agreed that “teaching and education within the university should continuously change and evolve” (strongly agree 52.5%, agree 37.8%). When asked about the future use of XR technology, 68.0% of all staff (n = 117) and 80.8% (n = 42/52) of staff members with previous XR experience “agreed” or “strongly agreed” that the university should make a substantial investment in XR technologies in the near future (11.6% (20/172) disagreeing; Figure 2a).

### General Attitudes and Desire for Inclusion of XR Technology in Teaching

| Courses (School) | Technology type | Teaching goal/learning objective/outcome | Inception of development | Implementation strategy | Estimated usage per course |
|------------------|-----------------|----------------------------------------|--------------------------|------------------------|---------------------------|
| Second year bachelor (Nursing and midwifery) | VR | Skill based procedural training | 2016 | Pilot project: rental system of hardware, unsupervised | 50 |
| Second year bachelor (Nursing and midwifery) | VR and respiratory biofeedback | Practical skill training and exposure | 2018 | Pilot project: integration into existing laboratories/workshop, supervised | >100 |
| Second year bachelor (Nursing and midwifery) | VLE and VR | Knowledge transfer/ bridging gap from textbook to practice | 2017 | Pilot project: remote access via online platform and supervision in class | 50 |
| Second year bachelor (Biomedical sciences and pharmacy) | AR and VR | Knowledge transfer and visualization | 2016/2017 | Pilot project: integration into existing laboratories/workshop, supervised | 60 |
| Second year bachelor (Electrical engineering and computing) | VR and AR | Example and case study | n/a | Subject matter in tutorial, supervised | n/a |
| All courses in bachelor (Health sciences) | VLE | Practical skill training, exposure, and visualization | 2011 | Remote access via online learning platform (blackboard), unsupervised | 100–140 |
| Second year bachelor (Health sciences) | VR | Practical skill training | 2017 | Remote access via online learning platform (blackboard), unsupervised | 40 |
| Third year bachelor (Biomedical sciences and pharmacy) | AR | Visualization and exposure | 2018 | Remote access via online learning platform (blackboard), unsupervised | 25 |
| Multiple online courses (Education) | Mixed reality | Practical and repetitive skill training | 2017 | Remote access via online learning platform (blackboard), unsupervised | Unknown |
| Online, post-graduate course (Business) | Virtual space with integrated external avatar interaction | Skill acquisition and consolidation, exposure to technology | 2017/2018 | Remote access via online learning platform (blackboard), unsupervised | 35 |
| First year (Architecture and built environments) | AR and VR | Exposure to technology | n/a | Integration via exhibitions and events, voluntary exposure in class, supervised | 50 |
| All courses within bachelor (Architecture and built environment) | VR and VLE | Knowledge transfer and practical skill training | 2018 | Remote access via online learning platform (blackboard) or web portal, unsupervised | 25–250 |
In addition to an overall positive attitude toward integration of XR technology, current teaching staff also expressed a willingness to actively integrate the technology into their courses. The majority of teaching staff (77.1%; 74/96) indicated they would use pre-developed, off-the-shelf XR teaching tools and 74.7% (71/95) would develop their own content, if given the opportunity (Figure 2b and c). No statistical difference in attitude was detected between teaching staff who had previous experience with XR technology, compared to those who did not. However, a trend was detected indicating that teaching staff who have been exposure to XR may be more willing to develop XR tools in the future ($p = .63$, nonparametric Wilcoxon rank test, Figure 2c).

Interviewed innovators were generally very enthusiastic about their XR teaching tools and expressed a strong desire to continue use in the future. Most (8/13) indicated that they have plans to expand their XR applications, although four of these indicated a requirement for additional infrastructure and/or funding support.

**Value Areas of XR Technology**

Staff and students were confident that XR technology can assist with teaching and learning, regardless of whether they have previous experience with the technology (Figure 3). The most applicable areas for the use of XR technology include:

- **XR is a powerful tool/should be utilised at universities**
- **XR is a distraction from teaching goals and learning objectives**
- **XR is a passing trend**
- **XR is a valuable tool/should be utilised at universities**
- **XR is not a distraction from teaching goals and learning objectives**
- **XR is not a passing trend**
- **XR is not a valuable tool/should not be utilised at universities**
- **XR is a distraction from teaching goals and learning objectives**
- **XR is a passing trend**
- **XR is not a powerful tool/should not be utilised at universities**
- **XR is not a valuable tool/should not be utilised at universities**

**Figure 1.** Staff and student attitudes toward XR technology in tertiary education. Weighted averages ± SEM, based on 194 staff and 299 student responses (a), 192 staff and 296 students (b), and 172 staff and 287 students (c). Responses were collected for all staff and students, regardless of previous experience with XR technology or position. Non-parametric Mann Whitney test showed no statistical difference between groups for any question.

Note: UON = The University of Newcastle.
technology were procedural training of activities of high risk or high costs (80.31% staff, 76.83% students; extremely and very confident); workflow familiarization (65.62% staff, 61.15% students); and flexible, off-site, and remote delivery of content (66.67% staff, 61.28% students; Figure 3). Again, staff with previous XR experience were more favorable toward its teaching capability, despite no statistical difference in responses. Similar results were observed between responses from students who had used XR technology in a course versus those who had not (data not shown).

Existing XR tools used at The University of Newcastle addressed a range of teaching goals. Practical skill and procedural training were most frequently reported (7/12 tools), followed by exposure to a scenario or environment otherwise not accessible (5/12), knowledge transfer (3/12), visualization (2/12), and use as an example/case study (2/12).

Figure 2. Staff support for XR uptake and investment. Staff responses displayed for those with previous experience in the use of XR in teaching (n = 52) and those without (n = 120) (a). Responses exclude staff in non-teaching roles, filtered based on those with previous experience with XR (n = 44) and those without (n = 87) (b and c). Non-parametric Mann Whitney test showed no statistical difference between groups for any question.

Note. p = .7619 (a); p = .635 (b and c). UON = The University of Newcastle.
Structured Evaluation and Impact of XR Teaching Tools

Although all interviewees reported that integration of XR technology improved teaching and learning outcomes, very few objectively evaluated these factors. Only three of the teaching tools were subjected to a formalized pilot or implementation trial study to assess outcomes.

Six of the tools were assessed in an unstructured fashion by the innovators prior to implementation. They sought informal feedback from a convenience sample of students. However, the approach was unstructured, and no data was documented or reported. Of note, two innovators specifically noted the importance and value of this preliminary feedback as it resulted in development of supporting materials/instructions to support practical implementation.

Interviewees reported that XR tools were received positively by students. Some indicated a potential to optimize/improve specific aspects of the application. For example, in one application a mistake was identified during student testing. However, this error could not be rectified there was no option to reengage with the developers without additional funding.

Despite reporting issues with ongoing support and implementation, all innovators were confident that the XR tool improved learning outcomes and that students were interested and positively engaged with the technology. Nine innovators stated that the XR application helped bridge an existing gap, whilst specifically highlighting that the tool was used in addition to, and did not replace, more traditional teaching methods.

Concerns and Barriers for the Scalability of XR Technology in University Education

In the online survey, 58% of staff and 63% of students indicated no concerns about the future use of XR technologies at The University of Newcastle (Figure 4a). Note, this specific question asked participants to report concerns other than those related to practical implementation and funding, which were captured elsewhere in the survey. Despite this stipulation, in an open-ended question asking participants to specify any concerns, 35% of staff and 56% of students indicated infrastructure support and/or implementation were a concern (Figure 4b).

Concerns reported in open-ended questions were categorized by topic area. The most commonly raised concerns by both staff and students centered on potential impacts of XR technology on learning outcomes (78% staff, 57% students; Figure 4b). Further, 44% of staff and 40% of students specifically mentioned concerns that XR technology may not be tailored to learning outcomes and have unintended negative effects on learning. The following quotes reflect aspects of this theme:

- “Program delivery must always be pedagogically-based. I would be concerned that new technologies would become the focus, and not the content used in them”—staff member.
- “It [XR technology] should only be used where a clear educational case can be made, not just as a gimmick”—student.
Another common theme, particularly amongst students, was a reduction of face-to-face learning and real-world practical experiences. Example quotes highlighting this concern include:

- “My main concern would be over reliance and removing the important social face-to-face development of young minds”—staff member.
- “...I don’t think it [XR technologies] should completely replace standardized learning practices”—student.

When asked about the biggest barriers for implementation of XR technology within the next 5 years, 75.6% of staff (n = 130) indicated funding, 62.2% (n = 107) the need for support and ongoing content refinement, 47.7% (n = 82) procedures for software development, and 47.1% (n = 81) mentioned staff compliance (Figure 4c).

Interviewees were reluctant to comment on the broader use of XR technology as a scalable approach for teaching across the university. Lack of infrastructure to support ongoing sustainability was mentioned by 12 of 13 interviewees, when they were prompted to comment on the future use of XR. Many innovators indicated difficulties/barriers with ongoing IT support and limited ability to refine or adjust content. Specifically, integration of XR technology into the existing IT infrastructure was identified as difficult. All the interviewees not directly involved in the development of the XR teaching tool (n = 9) indicated frustration at not being able to change or refine the tool for their specific needs.
Innovator Approaches for XR Development and Implementation

The majority of XR tools in use (10/12) developed specific XR software content. In 7 of these 10 cases, development of software was facilitated as part of a pilot scheme to support innovative technologies, by an in-house IT team. The remaining applications (3/10) were developed by external contractors, by academic teaching staff themselves or through sourcing of pre-existing applications from an external collaborating university.

Interviewees who worked with an in-house IT team indicated a high level of involvement in the process. Although they stated this to be desirable approach, they also noted that the process was a substantial time commitment and required considerable initiative particularly in the initial scoping phase. Time from conception to final delivery of the XR application ranged from 6 months to 2 years depending on the run time of the application and its complexity (i.e., number of distinct interactions with digital objects and number of custom-designed assets required). Although tools developed directly by teaching staff themselves took less time to develop (around 1–3 months), the concept and scoping phase took many months and years. Nearly all innovators stated that their involvement in the development was time-consuming but enjoyable and in most cases worth the increased demands and commitment.

All XR tools were developed/sourced for a specific course or degree program, and as such the mode of delivery and implementation was considered prior to or during the initial planning phase. Innovators indicated that implementation was largely managed by themselves (or in collaboration with the teaching team), with no access to central infrastructure, facilities, or funding within the university.

Only three XR teaching tools are fully integrated into the curriculum and made compulsory for students. All other teaching tools (9/12) were provided as an additional, non-compulsory resource for students to explore. These were set within pilot testing projects. Six of the XR tools were integrated into existing courses or tutorials, where teaching staff brought and set-up the hardware themselves. Interestingly, both VR applications which were developed to be delivered either using a HMD or PC resulted being used as VLEs. Together with third VLE these teaching tools were distributed via online teaching platforms and accessible remotely and by students on their own time. A further three teaching tools were accessed using a booking system, to either a XR-dedicated room, a XR-enabled teaching session with an educator on-hand or borrowing of hardware for self-guided use. Only one teaching tool was used during assessments.

Discussion

Our study assesses the current state of XR technology usage and distribution across the University of Newcastle and the general attitudes of staff and students. The data indicates a general readiness and positive perception toward XR technologies in higher education despite limited individual exposure and integration into teaching courses. Only a small number of XR teaching tools (n=11) have been developed and explored as teaching tools within the University as of 2019, and most applications have been prototype tested within pilot projects. Teaching staff involved in these projects were interviewed and provided valuable insights on the crucial importance of ongoing support and sustainment beyond the initial build, to support ongoing use of the tool. Further, innovators highlighted the value of XR teaching applications, describing it as an extremely useful additional teaching resource to bridge gaps, while noting it is unlikely to replace existing face-to-face approaches.

Current State of XR Teaching Tools in University Education

At The University of Newcastle, the use of XR technology as a teaching tool is in its relative infancy, yet to be functionally integrated or adopted across our institution. While some staff and students reported previous exposure to the technology, there was limited experience in a teaching setting. Despite development of some innovator-driven pilot projects the overall number of VLEs and XR tools remains modest (n=12). Further only very few of these pilot applications have been integrated into the teaching curriculum.

Our searches indicate that other universities, both in Australia and worldwide, may be at a similar stage of integrating XR technology largely via small-scale and short-term pilots (Barteit et al., 2021). Many institutions have launched initiatives to promote staff engagement and exposure to XR technology, including funding of specific pilot projects (Brinkworth et al., 2009; Powley, 2019; Krokos et al., 2019; Radianti et al., 2020). Of note, information on current initiatives, pilot projects, and scalable use of the technology are largely available in press releases and on organization websites. Overall, very little information on the use of XR teaching tools or broader implementation initiatives was available in the academic literature, which could inform practical use and implementation of XR technology at an institutional level including integration into the existing teaching frameworks and course structure. This lack of information lead us to explore how XR teaching tools created at our own institution are being implemented and used in the current study. Valuable future research might survey the state of XR usage across educational institutions to identify generalizable avenues and barriers.

Unfortunately, very few of the developed XR teaching tools have transitioned from pilot-testing to long-term integration into a curriculum at The University of Newcastle. This is a surprising outcome, particularly as all educators interviewed described their XR tools as being useful teaching
resources. Ongoing funding, IT support, and integration as well as non-sustainable implementation strategies were named as major barriers for ongoing use. As a result, two VR applications transitioned from a VR to a VLE, presumably due to the ease of delivery using the online learning platform, despite evidence outlining the benefits for a more immersive in headset delivery of training content (Grassini et al., 2020). This finding strongly emphasizes the need to address questions around support and implementation strategies together with the development of XR teaching tools to ensure their utility.

We were unable to find literature describing the successful and scalable integration of XR technology at any Australian university. With so little information available, it is difficult to develop evidence-based strategies to inform successful implementation and diffusion strategies for the technology in higher education.

Despite limited existing evidence, the increasing numbers of reported pilot studies and web articles on the topic suggest a general desire and potential future for XR technology in higher education. This attitude was evident in feedback we obtained from our staff, which clearly indicated a strong belief that the technology will transform the teaching landscape in the future. Similar sentiments are being voiced in theoretical papers on the potential of the technology and student feedback studies (Baxter & Hainey, 2020; Gurevych et al., 2021; Ziker et al., 2021). Given the general readiness and growing enthusiasm in the broader university population (beyond existing XR innovators), expanded use of XR technology in higher education may only be a matter of time.

### Leveraging Experience: Informing the Future Use of XR Technology

To address how (or even whether) broad uptake of XR in higher education will be possible, we assessed the approaches used by innovators and the feedback provided by staff and students to help inform a potential scalable XR framework.

A consistent point raised by innovators was the view that XR teaching applications represent an additional teaching tool, complementing rather than replacing existing practices. The use of XR as a teacher/tutor-facilitated and integrated resource rather than a stand-alone teaching approach strongly resonated with feedback provided by staff and students. Numerous concerns were raised that increased use of XR technology may reduce face-to-face teaching and real-world learning, a prospect viewed as largely negative. It is important to highlight the framework in which XR technology will be used, as the effectiveness of any new teaching approach must consider and is dependent on its integration into the existing teaching culture and environment (Proserpio & Gioia, 2007; Rogers, 2003; Straub, 2009).

Here we show that the approaches used for the development of XR prototypes and research-focused pilot projects alone are unlikely to directly inform a scalable adoption and integration framework.

Firstly, individual pilot projects driven by motivated innovators required extended development timeframes and a high level of staff commitment, input, and initiative, which is unlikely to be broadly scalable across the university. Secondly, the context in which pilot applications were developed, tested, and implemented largely failed to capture relevant data metrics that could inform broad implementation and technology adoption.

Despite approaches used by innovators not being directly scalable, interviews with innovators did identify key barriers and important areas for further research. One of the biggest barriers, besides initial funding, was ongoing support for hard- and software.

Specifically, this includes the ability to refine application content, IT/infrastructure integration, and ongoing maintenance support after the prototype build.

The initial costs of content development are high, these costs are often clearly defined. In contrast, the costs and infrastructure required for ongoing sustainment are difficult to predict a priori and are often not considered during the innovation phase of technology adoption. We highlight that failure to consider ongoing sustainment was the main reason many of the developed XR applications were discontinued. Many interviewees reported frustration at the inability to make minor, but critical, adjustments to content after development was complete. For example, one interviewee stated: “There is currently no contingency plan to use the tool after pilot testing, due to lack of funding to fix minor technical issues, maintenance, and updates.”

Difficulties in accessing infrastructure services (e.g., IT support) largely appeared to originate from the same circumstances of relative freedom that allowed innovators to pilot and develop novel teaching applications in the first place. As such, innovators typically created their applications without broad input across relevant university departments (e.g., department executives, IT specialists). However, due to limited direct involvement and approval from these stakeholders ongoing funding and support for the XR teaching resources was difficult to secure and considerations of ongoing aspects required for technology sustainment were often not considered (or budgeted for).

Broad scale institutional level involvement in XR expansion has been investigated at the University of New South Wales (“The Inspired Learning Initiative,” 2019). Their “Inspired Learning Initiative” sought to investigate supporting existing educators and programs. Internationally, the University of Michigan launched a similar “Extended Reality Initiative” in 2019 to fund the development of XR applications and projects assessing aspects of XR content creation, deployment processes, and effectiveness for teaching (DeVaney, 2019). Further, numerous organizations across the United States of America have collaborated...
on an industry-funded, multi-year research project in an attempt to address numerous questions regarding the use of XR in education, the “HP/EDUCASE Campus of the Future Project.” This project is focused on the promotion of institutional adoption of technologies for research, teaching, and learning and includes a range of use cases and approaches toward implementation (Pomerantz, 2019).

**Study Limitations**

The data presented in this study has been collected from a single university. As such the biggest limitation, be connected to the direct generalization of our findings. However, they are likely transferable and more importantly can aid educators and institutions in identifying critical areas of importance and may help shape decision making processes around the adoption of XR technology within their own specific circumstances. Further, the response rate to our online survey was relatively low (1% of all students and 7% of all staff), but is consistent with similar university-wide general expectation and attitude studies (Brinkworth et al., 2009; Hassel & Ridout, 2018). Due to the random sampling approach, caution should be taken when extrapolating findings to the total population as there may be self-selection bias for respondents who have experience or are interested in XR technology. Despite this potential bias, we noted very low levels of experience with XR technology among respondents overall. We note that our interview population of innovators was relatively small (n=12). Another limitation was the use of survey questions which were not formally assessed for construct validity or reliability. Each individual question was generated to gather context specific-attitudes and perceptions from students and staff at the University of Newcastle. Internal consistency was confirmed by including both positively and negatively worded questions for relevant constructs. Face- and construct validity were considered during the development of questions by including feedback from experienced educators and executive staff. Every effort was made to identify all university teaching staff with direct involvement in developing and implementing XR technology at The University of Newcastle. Whist the importance of underlying learning theories for the development of XR teaching tools has been highlighted in the literature this aspect was not specifically raised in the interviews with innovators. Despite these study limitations, we believe the data captured will be of broad general interest to people involved in higher education and XR teaching tool development and provides useful insights to the current state of XR technologies at an Australian university.

**Conclusion**

While XR technology is used at our institution, the developed tools are not widely adopted or sustainably supported. Critically, the existing XR applications at our institution, whilst identified as valuable and effective within their context, provide only very limited insights to inform broad scale utilization of the technology across the institution and in the future. Our data indicates a general optimism, perception of value and willingness to adoption XR technology from both staff and students, whilst also bringing to light a sense of uncertainty around how this may be facilitated on a broad scale. Existing barriers to broader XR technology use included funding, infrastructure, ongoing support, and maintenance. This conclusion is likely transferable across educational institutions. When (or whether) XR will become the future of teaching and learning will therefore largely depend on the willingness of institutions to implement change and commit resources to identify, develop, assess, and validate scalable approaches with limited existing guidance. We propose future research activities to expand from classical pilot testing approaches to include strategic impact assessments. Anecdotal or perceived benefits to student experiences may not be enough to support public spending. Instead, rigorous evaluation of the learning outcomes, student reach, and impact will identify the cost benefits of XR and help make an evidence-based discussions for the future of the technology in higher education.

**Acknowledgments**

We acknowledge ongoing support and assistance from the Deputy-Vice Chancellor (Academic)’s office, specifically Rebecca Reynolds and Louisa Connors, particularly for their assistance promoting the online surveys. We also acknowledge the input and support from Shanthi Ramanathan at Health Research Economics, Hunter Medical Research Institute, during study design and her feedback on survey questions and evaluation approach. We also thank all members of the Centre for Advanced Training Systems for their input and discussions relating to project development, conduct, and data interpretation.

**Availability of Data and Materials**

Interview transcripts and survey responses collected and/or analyzed during the current study are not publicly available due to privacy considerations. Summary data beyond that included in the manuscript is available from the corresponding author on reasonable request.

**Declaration of Conflicting Interests**

The author(s) declared the following potential conflicts of interest with respect to the research, authorship, and/or publication of this article: Author DJRE was the Deputy-Vice Chancellor (Academic; DVC-A) at The University of Newcastle at the time of project conception and research inception but has since stepped-down from this role. All other authors declare that they have no competing interests for the current study.

**Funding**

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This
research was funded as the Digital Simulation Technology Evaluation Pilot (STEP) project within the NeW Education Framework through The University of Newcastle DVC-A’s office.

**Ethical Approval**

All research was reviewed and approved by The University of Newcastle Human Research Ethics Committee (Study reference: H-2019-0065).

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**Supplemental Material**

Supplemental material for this article is available online.

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