#12: VR/AR TECHNOLOGIES IN VOCATIONAL EDUCATION AND TRAINING – SCOPING STUDY

FINAL REPORT – FOR PUBLIC

Building 4.0 CRC Project # 12

VR/AR Technologies in Vocational Education and Training – Scoping Study

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EXECUTIVE SUMMARY

The vocational education and training (VET) sector in the Australian context has a critical role in preparing or updating current or future employees with job-related skills required in the workforce. In the construction industry, VET qualifications ensure trades and employees have the required knowledge and skills to work effectively, sustainably, and safely, following the Australian Qualification Framework (AQF). Therefore, the construction industry is highly regulated via VET programs that provide licensing requirements to many construction occupations. It is expected that the number of VET-related occupations will increase in the coming years in the industry thanks to a growing demand for skilled workers due to construction project development. These requirements imply significant pressures to update the training delivery approaches in the construction VET system.

Besides a growing demand for skilled workers, the construction industry is experiencing significant digital disruption, altering how workers interact and operate. Technological advances and industrialisation demand a new skill set in VET graduates to reach higher productivity levels. Skills such as digital literacy, complex problem solving, judgement and decision making will become essential for VET graduates to respond to 21st-century market demands. This tendency triggers changes in the educational and training approaches used in the VET sector to ensure trainees are introduced to real-world scenarios where they can develop or update their work-related skills aligned with 21st-century conditions. In response to these workforce and technology pressures, this project studied the implications and opportunities of integrating immersive learning in the VET training delivery process to enhance trainees' job-related skills.

Findings for this project were obtained from a literature review, market survey and a Delphi study. The literature review aimed to investigate the current state of the art of extended reality (XR) technologies and immersive learning in construction education and training. After that, the market survey, and particularly the Delphi study as a research approach, were selected to propose a decision-making process to determine appropriate XR technology for specific skill training in the construction industry. The report summarises the most significant factors that VET educational providers should consider when selecting XR technologies to be implemented in VET training programs. The report also presents a workflow process for translating conventional vocational skill training into immersive learning using XR technologies and virtual reality/augmented reality environments. Finally, implications for trainers are discussed.

It is expected our findings will be used as a benchmarking guide for future research towards commercial implementation and immersive learning prototype development for workforce capacity improvement in the building and construction industry.

Vocabulary

- Conventional training approach: Approach based on simple multimedia presentations or in-person classroom teaching.
- Extended reality (XR): all real-and-virtual environments/technologies used in immersive learning.
- Trainee(s): refers to VET students, learners, or appendices.
- Trainer(s): refers to VET professors, lectures, or teaching staff.

1. BACKGROUND

1.1 Vocational Education and Training (VET) in Australia

VET in Australia provides qualifications and high-quality training to all working-age Australians to address the demands of the labour market and contribute to Australia's economy and productivity. The primary role of VET is to prepare Australians with occupational and work-related skills and knowledge based on a practical perspective rather than an academic or theoretical one. The following data helps discern the importance of VET as an education sector in the Australian context. Between 2018 and 2019, there were 1 million more VET qualifications than higher education qualifications (Hall & Stanwick, 2021). Moreover, it was estimated that 21.7% of the Australian resident population aged 15 to 64 years participated in nationally recognised VET in Australia, and 3.9 million trainees were enrolled in VET programs in 2020 (NCVER, 2021). Therefore, the relevance of the VET sector in Australia in contrast to tertiary education is settled on preparing working-age Australians without professional experience to enter the workforce or refining their specific work-related skills to reach market demands.

Indeed, VET directly enhances the employability status of working-age Australians and simultaneously supplies qualifications of occupations in demand according to new requirements. For instance, an estimated 56% of qualification completers in Australia improved their employment status in 2020, either obtaining better employment or getting a new job after being unemployed before training (NCVER, 2021). This data highlights the VET sector's critical role as a significant part of Australia's education system, helping Australians adapt to changing skill needs throughout their careers according to new market demands (Montague et al., 2017). This data also raises awareness of the high responsibility of the VET sector to constantly update job-related skills to ensure trainees are prepared to work in new and 21st-century conditions. Therefore, it is essential to understand the structure of this sector and examine the spectrum of VET qualifications in Australia to appraise the complexity of targeting VET skillsets aligned to new market demands.

1.1.1 Structure of VET qualifications

The Australian Qualifications Framework (AQF) (Department of Education Skills Employment, 2013) provides the standards and specifications for each VET qualification. These qualifications are categorised by factors and qualities into certificates I, II, III, IV, diploma, and advanced diploma (Figure 1), determining the professional profiles of graduates prepared to enter the workforce.

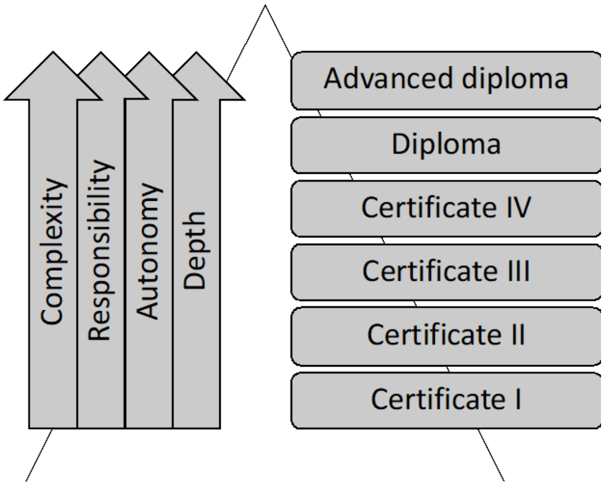

Figure 1. Australian Qualifications Framework – VET training (Adapted from Montague et al., 2017)

AQF differentiates each VET level according to the learning outcomes, which at the same time are measured in terms of knowledge, skills, and the application of knowledge and skills (Department of Education Skills Employment, 2013). These dimensions vary according to different factors that are listed in Table 1.

- Certificate I graduates develop skills and knowledge for initial work and community involvement.
- Certificate II graduates obtain knowledge and skills for work in a defined context.
- Certificate III graduates develop theoretical and practical knowledge and skills for work.
- Certificate IV graduates acquire theoretical, practical knowledge and skills for specialised and/or skilled work.

In addition, students can obtain specialised knowledge and skills for skilled/paraprofessional work as part of a diploma.

Table 1. Dimensions and factors to characterise VET Qualifications (Adapted from Department of Education Skills and Employment, 2013).

Dimensions	Measurements
Knowledge	Depth, breadth, kinds, and complexity
Skills	Cognitive and creative, technical, communication, and interpersonal skills
Application of knowledge	Autonomy, responsibility, accountability, and the context where the graduates interact

In short, certificate I and II graduates work in routine and stable contexts with autonomy but limited judgement implementing defined tasks. As a result, these graduates require supervision, unlike Certificate III graduates, who have more responsibility for solving unforeseen problems (Montague et al., 2017). On the other end, a diploma provides a deeper understanding of a particular field, and an advanced diploma prepares students to work as a paraprofessional. The difference is that diploma graduates use judgement to make decisions in complex projects, and advanced diploma graduates can perform specific tasks demanded in a field without being fully qualified.

The range of qualifications explained previously aim to respond to the demand for different skilled profiles in the industry. Thus, each qualification demands a targeted teaching and training process to promote and develop specific knowledge and skills. This targeted teaching/learning implies the cautiousness of educational providers when designing teaching/learning approaches and activities that will ensure the development of appropriate skills sets based on certain levels of autonomy, responsibility, and context complexity where graduates interact (Table 1).

In other words, the VET sector requires to promote teaching/learning mechanisms that help students acquire pertinent knowledge to develop skills for working in specific environments. For instance, while the teaching activities set in a diploma qualification should encourage creativity skills to allow students to work on unforeseen problems, in Certificate II, teaching activities are directed towards basic skills to be used in a defined context. Therefore, constant supervision and control of VET programs are essential to ensure teaching/learning mechanisms align with the intended learning outcomes. This supervision is even more critical in the construction industry because new skills have arisen as part of technological development. Still, the industry suffers job-specific and technical skills' shortages (Toner, 2003). Therefore, the following section explains the current state of VET qualifications in the construction industry and the new challenges boosted by new market demands.

1.2 VET qualifications in the construction industry

The VET sector is recognised as being decisive in the construction industry to prepare current and future employees for the workforce providing the appropriate technical, personal, and interpersonal skills. As a result, this industry has increasingly been employing more people with VET qualifications. As shown in Figure 2, the construction industry employs approximately 1.16 million persons, representing roughly 8.8% of Australia's total workforce (AISC, 2021). In 2020, approximately 43.5% of the construction workforce held a VET-related qualification (AISC, 2021). Importantly, it is estimated this proportion will rise to 74.2% by 2024 (Figure 3) partially because of the higher demand of licensing requirements.

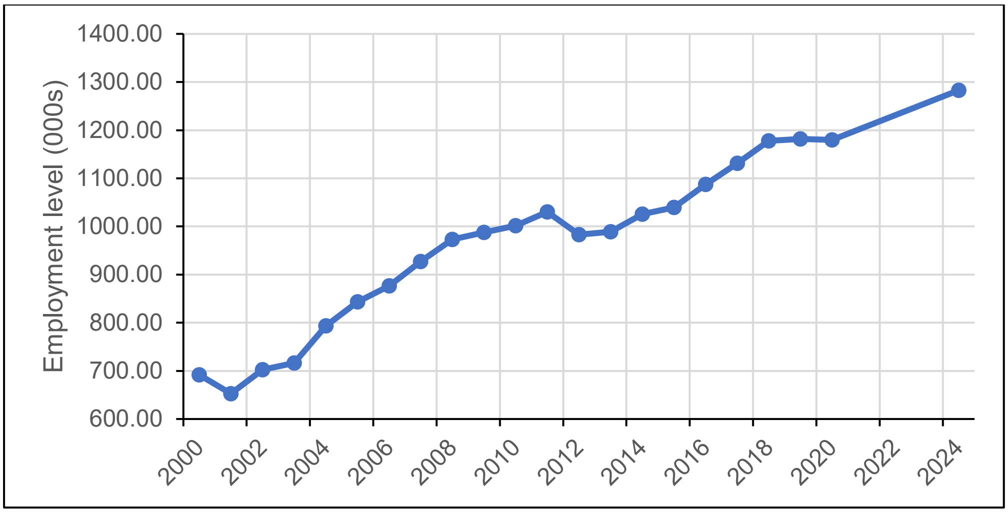

Figure 2. Employment level and projection in Construction (Reproduced from AISC, 2021).

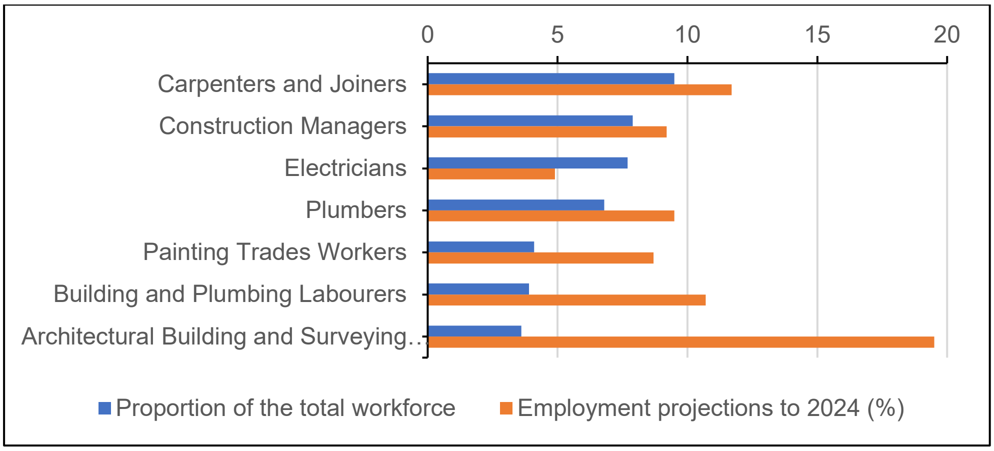

Figure 3. The proportion of VET related occupations of the Construction workforce (Reproduced from AISC, 2021).

Based on NCVER (2021), in 2020, architecture and building programs had approximately 203.275 enrolments in Australia, representing almost 7.7% of the total enrolments in the VET system. In addition to program enrolments, the construction industry is highly dependent on VET licensing requirements that apply to professionals in different subdisciplines. Indeed, VET subject enrolments in this industry outnumbered VET programs enrolments by nearly 1.07 million. This evidence supports the idea that one of the primary roles of VET in the construction industry is related to these kinds of licensing requirements, which provide students with appropriate skills to ensure a high level of quality and responsibility when performing high-risk work.

This evidence suggests the demand for licensing requirements in the construction industry generates a higher number of enrolments in the VET certificates (Artibus Innovation, 2020) . Figure 4 depicts the number of VET program enrolments per level in Australia between 2016 and 2020. As can be observed, the program enrolments in diploma and advanced diploma courses are significantly low compared with certificate courses. Surprisingly, the number of VET program enrolments in certificates I and IV has decreased across the years. Notably, Certificate III has consistently higher enrolments, with almost 83,555 in 2020 representing 41% of all VET program enrolments. This means VET qualifications are mainly demanded in the construction industry to introduce graduates to further learning in predictable problems using known solutions. Beyond this, consistent with predictions discussed earlier (Figure 3), the VET system is expected to become even more crucial for the Australian construction industry in the coming years, reflecting the growing demand for skilled professionals in large scale projects that have generated skills' shortage.

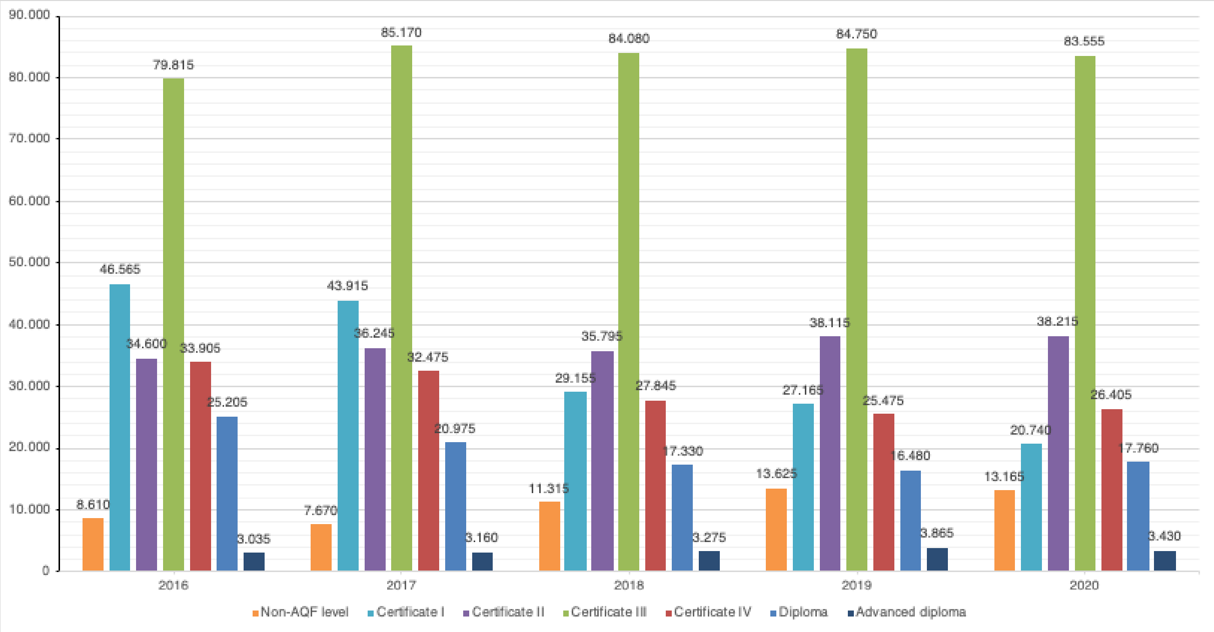

Figure 4. Program enrolments per level of education in Architecture and Building in Australia (Adapted from NCVER, 2021).

One major challenge for VET in the construction industry is that while the demand for skilled workers increases, the industry suffers job-specific and technical skills' shortages (Toner, 2003). Predictions show Victoria's construction industry, with an annual growth of 3%, will need to double its employment by 2046 (Deloitte Access Economics, 2016). Similarly, Infrastructure Victoria (2016) highlights the growing demand for a skilled workforce in the next decade to respond to its 30-year infrastructure strategy. In addition, almost 37% of Victorian employers in the construction industry in 2017 agreed the recruitment process was problematic because professionals did not have the required job-ready skills (Department of Education and Training, 2017). The shortage becomes even more severe with the increased number of unsuccessful apprenticeships in Australia (Mangan & Trendle, 2008).

The construction industry's skill shortage is a direct consequence of a continuous drop-off in the apprentice training rate (Toner, 2003), an increased cancellation rate of apprenticeships (Mangan & Trendle, 2008) and quality issues in the VET system (Snell & Hart, 2007). For instance, Bilginsoy (2003, p. 67) suggests the high cancellation rate of apprenticeships in the United States can generate costly disincentives because employees are dissatisfied with the vocational training. In Australia, literature argued the increased number of unsuccessful apprenticeships is a consequence of variables such as disability and non-English speaking background that represent a disadvantage for trainees in the labour market (Mangan & Trendle, 2017). These results suggest an imperative for VET to restructure its teaching/learning approaches based on employer requirements to skill trainees with the appropriate job-related skills required in 21st-century environments. Simultaneously, this restructure will improve the quality, performance, and efficiency of VET programs. Further, if the skilled professional deficit is not tackled based on new market demands, the gap between the demand for and supply of skilled workers demand could lead to increasing operating costs and workloads for other workers, impacting industry productivity (Department of Education and Training, 2017).

Besides productivity issues, the construction industry could experience numerous adverse results if the shortage of skilled professionals increases. First, the skill deficiency extends construction times, especially in the volume building industry (Dalton et al., 2013). The second outcome relates to defects. Numerous complaints have been reported about construction workmanship and consequent defects distinguished by inadequate skills, wrong application of materials, deficient supervision skills, and poor qualities of work carried out onsite (Georgiou, 2016). Hence, there is a need for better skill practice within the construction sectors. In short, the lack of job-specific skills suggests employers rely on private training providers, including TAFEs and other industry associations, to prepare the current workforce with the appropriate skills for 21st-century construction projects, which will increase the industry's productivity levels.

The data described in this section suggests the construction industry uses and requires vocational training to prepare professionals with cognitive, technical, and interpersonal skills aligned to different professional profiles in the workforce. As noted earlier, the number of construction VET qualifications is expected to increase in the coming years due to new development projects. However, employers have experienced issues in recruiting skilled construction professionals, mainly because applicants do not have the appropriate job-related skills. Thus, one of the challenges for the VET sector is to tackle the skills shortage that is putting the productivity and performance of construction projects at risk.

Besides the growing demand for skilled professionals in the construction industry, which represents considerable pressure for the VET sector, technological changes boosted by the fourth industrial revolution have changed the skillsets required in the construction workforce. Further, new technology adoption and industrialisation have altered how construction projects work and operate, requiring new digital skills to reach higher productivity levels. This represents a further challenge for the VET system: update skills to respond to new market demands related to technological change and globalisation as part of the fourth industrial revolution (Skills Senior Official's Network, 2021) or industry 4.0. (Wibrow et al., 2020).

1.2.1 Opportunities and challenges in construction VET qualifications: new skills in the 21st century

Technological advancement in VET represents both opportunities and challenges. On the one hand, the Australian workforce needs new disciplines and digital skills to respond to globalisation conditions. Thus, VET must address the skill shortage in critical and emerging industries (Montague et al., 2017) to contribute to productivity growth and economic prosperity. On the other hand, the novel technological usage potentials boost the update of work-related skills, increasing the pressure in VET quantifications to make the most desirable use of modern technology tools to enhance teaching/learning approaches. While 21st-century skills are constantly changing towards a more competitive and productive perspective, updating and controlling VET qualifications and licences is essential to align learning outcomes with these new approaches.

This century has been characterised by the rapid advancement of technological adoption and industrialisation. This process has altered how industries and sectors work and operate, demanding new skills to reach higher productivity levels. As a result of these changes, the Australian national and jurisdictional governments proposed a VET reform roadmap for a new National Skills Agreement (Skills Senior Official's Network, 2021). The Council of Australian Governments (COAG) presented the new VET roadmap composed of priorities to ensure the relevance, quality, and accessibility of programs aligned to the technological change of this century. For instance, this roadmap proposes developing integrated courses between higher education and VET content. Therefore, it is likely that such connections promote alignment in the lifelong learning students' pathways, upskilling/reskilling workers in digital training, and synergies to engage current students in technological advancement (Wibrow et al., 2020).

Aligned to this new skills demand and consistent with the prediction explained in the previous section, a report elaborated by TAFE Queensland (Reeson et al., 2016) suggests the number of VET enrolments in the future will drastically increase due to the emergence of new industries and the reskilling of mature workers. This report argues VET will require a shift in the provided skills to respond to technological advances. For instance, digital literacy will become one of the core skills in vocational training (Reeson et al., 2016). Importantly, digital skills should not be approached as technical skills in the VET context; somewhat, they should be related to the skills needed to work in the digital environment that will be more common in the 21st century (Wibrow et al., 2020).

Digital skills involve a wide range of capabilities and competencies. Each VET qualification will demand different skills according to the requirements of specific activities and work contexts. Gekara et al. (cited in Wibrow et al., 2020) classify the workforce's digital skills in four levels. The first level refers to a basic understanding and operation of the technology to obtain and transmit data. The second level concerns understanding, managing, and applying technologies to process data related to organisational operations. The third level refers to the innovative use of technologies to enhance the efficiency of corporate functions, and the last level is reached when workers have a digital culture and identity. This classification confirms the VET system must consider 21st-century requirements related to technological advances to restructure and update the learning outcomes of VET qualification in each education level aligned to new digital skills. For instance, certificates I and II still need a shift in their learning outcomes to prepare students to capture and transmit information in digital environments, not obstructing organisational operations. Therefore, the VET sector requires renewal in the teaching/learning approaches to promote new learning outcomes. These renewals should be matched with the latest technology and skills demands.

On the other hand, within the VET reform, new standards for VET qualifications will be considered to enhance students' practical expertise. One of the priorities settled as part of this reform is to include work-integrated learning (VIT) in vocational education, such as apprenticeships and traineeships (Skills Senior Official's Network, 2021). Although these strategies benefit students in terms of professional and practical experience, there could be several difficulties when implementing this approach. The main aim of apprenticeships and traineeships is to provide students with professional expertise facilitating the transition between training and real-world experiences. However, as was argued earlier, these strategies are not always possible because they require strong collaborations, and the trainees are affected by contract terms in some circumstances. Therefore, the VET sector cannot rely exclusively on the stimulus of apprenticeships. Instead, it should strengthen VET reforms related to teaching/learning approaches to meet new requirements in the industry towards a skills-led economic future.

The conditions described above suggest the conventional approach of construction education requires changes in the teaching delivery process to ensure the professional skills are targeted to real life and technological conditions in the 21st century. Conventionally, construction education has struggled to expose students to real-life scenarios where they can understand the systematic perspective of this discipline. Without field trips, visits to construction sites or practical experience, students struggle to understand the complexities of the different disciplines' designs and construction processes in conjunction with context constraints that depend exclusively on the location, stakeholders, and time of each construction project. Additionally, the 21st century has drastically changed construction work, in part because of advancements in new approaches such as Building Information Modelling (BIM) or Lean Construction that have revolutionised work and data management (Alizadehsalehi et al., 2020) and consequently provoked a shift in workers' skills. For these new trends, the construction industry requires re-evaluating traditional teaching approaches to boost recent efforts to enhance the professional and vocational. These new approaches should prepare and update trainees with hands-on experience and the knowledge to work and collaborate in digital environments.

Immersive learning emerges as an excellent cost-effective teaching/learning approach in response to the new digital skills demanded in construction trades. As noted earlier, Australia's VET sector needs to innovate and shift teaching approaches to align them with new market demands, given the sector "not only supports retraining and upskilling our national (Australian) workforce, but it is also a key enabler of emerging industries, new technologies and new ways of working" (Reeson et al., 2016, p. 1). Immersive learning has been shown to be an excellent teaching and learning approach in construction (CITB Research, 2017), with benefits such as better learnability, visualisation, creativity, motivation, and most importantly, real-world skills (Alizadehsalehi et al., 2019b).

Immersive learning exposes students to real-world scenarios without leaving the classroom and simultaneously equips students with digital skills required to solve 21st-century problems. While XR technologies have received much attention to improve productivity, safety, and efficiency levels (Chi et al., 2013), organisations and institutions have struggled to adopt and accept (Venkatesh & Bala, 2008) these technologies in their everyday processes (Rankohi & Waugh, 2013). In this century, the use of XR technologies in construction training has increased rapidly (P. Wang et al., 2018). However, most case studies in the literature have been limited to safety training simulations (e.g., Dhalmahapatra et al., 2021; Janaćković et al., 2018; Zhang et al., 2019). Likewise, these case studies have focused on the XR technology itself, ignoring its effectiveness in the organisational context and integration in multiple projects (Rankohi & Waugh, 2013). In short, no one, as far as we know, has studied from additional perspectives the integrated utilisation of immersive learning in vocational training to ensure XR technologies are used for specific vocational skills. This research assesses how immersive learning provides advantages when promoting job-related and digital skills in trainees who aim to join the workforce or upgrade their skills for new market demands.

2. LITERATURE REVIEW: IMMERSIVE LEARNING

Immersive learning is a teaching and learning approach that uses interactive environments to engage students in real-world scenarios. As pointed out by CITB Research (2017, p. 8), immersive learning "use(s) game-based techniques (such as collaboration, communication, problem-solving and visual immediacy) to replicate environments and scenarios, and practice skills". It uses online and digital environments integrated with face-to-face activities bringing trainers and trainees near real-work experiences. This approach relies on technology, the constructive perspective of students, and students' creativity.

As noted earlier, immersive learning is a potential solution in the construction industry to develop systematic perspective skills required to communicate the complexity of interactions between systems in construction projects. For instance, construction is often looked at as the area in civil engineering that integrates the perspectives and interests of the other technical areas (i.e., structural, geotechnical, water, transport engineering, etc.). However, conventional training approaches based on simple multimedia presentations and textbooks limit the trainers' capability to efficiently teach and explain to students the interaction between systems. Therefore, immersive learning is positioned as an effective teaching/learning approach that will help bring students closer to complex and practical problems in the construction industry.

While lower levels of innovation have commonly characterised the construction industry, construction companies and organisations have been implementing new methodologies and technologies to enhance productivity and efficiency in construction projects this century (CITB Research, 2018). Likewise, trainers have acknowledged the potential of immersive learning to promote and foster job-related skills together with collaboration and problem-solving skills. These skills help prepare students for the workforce, improving practical skills in real-world scenarios (CITB Research, 2017). This benefit represents a drastic difference from the conventional training approaches where hands-on and professional experiences are scarce. A literature review in XR technologies was elaborated even further to understand the current state-of-the-art of these topics in construction vocational education and training.

2.1 Overview of literature related to XR technologies in construction vocational education and training

XR technologies in the construction industry diversify learning environments and promote meaningful learning by creating a more realistic understanding of the learning phenomena. Although there are few cases in the vocational education sector, XR technologies, in most cases, have been adopted to expose trainees to real-world experiences. In other words, XR technologies have been designed to simulate construction sites as virtual environments where trainees can be immersed and interact. Therefore, immersive learning supported with XR technologies becomes an excellent alternative to enhance trainees' spatial understanding of complex construction systems (P. Wang et al., 2018). This is essential to strengthen job-related skills to get ready for the workforce.

Over the past few decades, the range and number of cases adopting XR technologies in construction training has grown substantially. A search in Web of Science and Scopus was done to analyse the scope and spectrum of these XR technologies in the construction sector. The following search strings were served in the current research using Boolean operators to obtain the related documents between 2010 and 2021: ["Augmented Reality"

OR "Virtual Reality" OR "Mixed Reality" OR "Serious Game" OR "Computer Simulations"] AND ["Construction"] AND ["Training" OR "Prefabrication"]. 250 out of 1064 publications were relevant to this objectives' research. As shown in Figure 5, the number of publications drastically increased since 2010, as was also suggested by Rankohi & Waugh (2013). Likewise, a complete analysis of the countries with more publications in these topics was done (Figure 6) to gain insight into Australia's current advancement. Figure 6 demonstrates US researchers are more active by far. Interestingly, Australia has the second most number of publications.

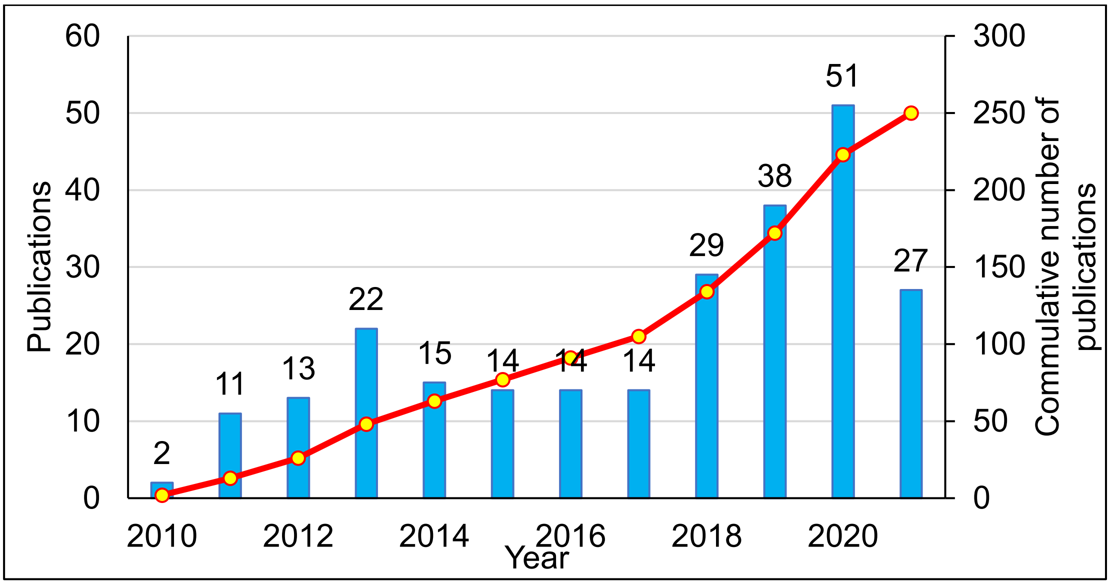

Figure 5. The number of XR publications in the construction sector since 2010.

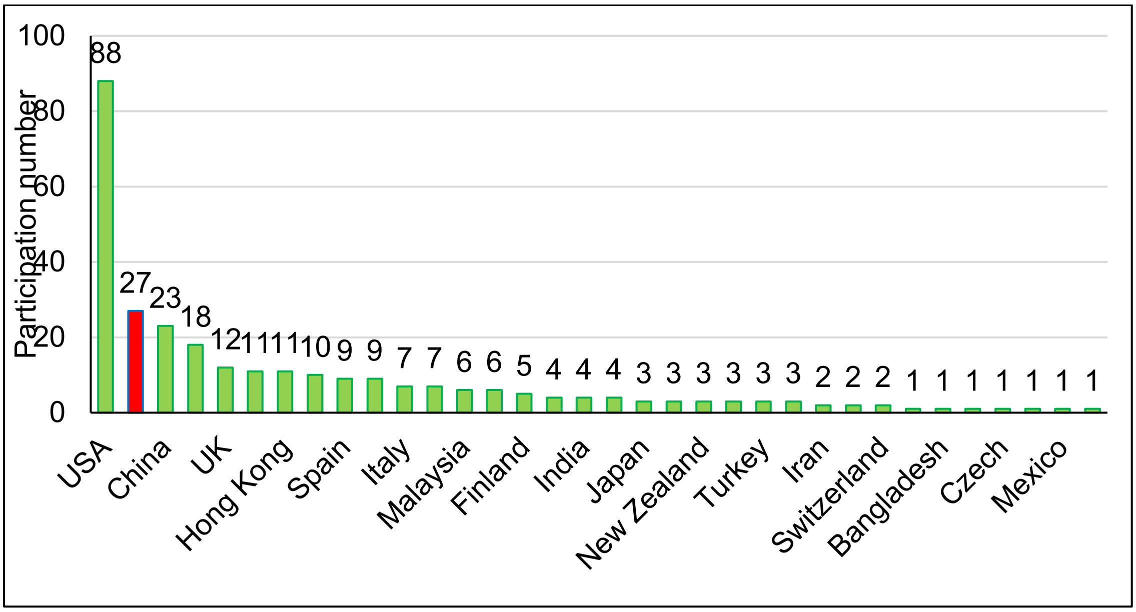

Figure 6. Countries with publications related to XR technologies in AEC.

Additionally, Figure 7 shows the names of related journals to the topic of this study and the number of papers published during the considered period. For example, the *Automation in Construction* journal, published by Elsevier, has the most documents.

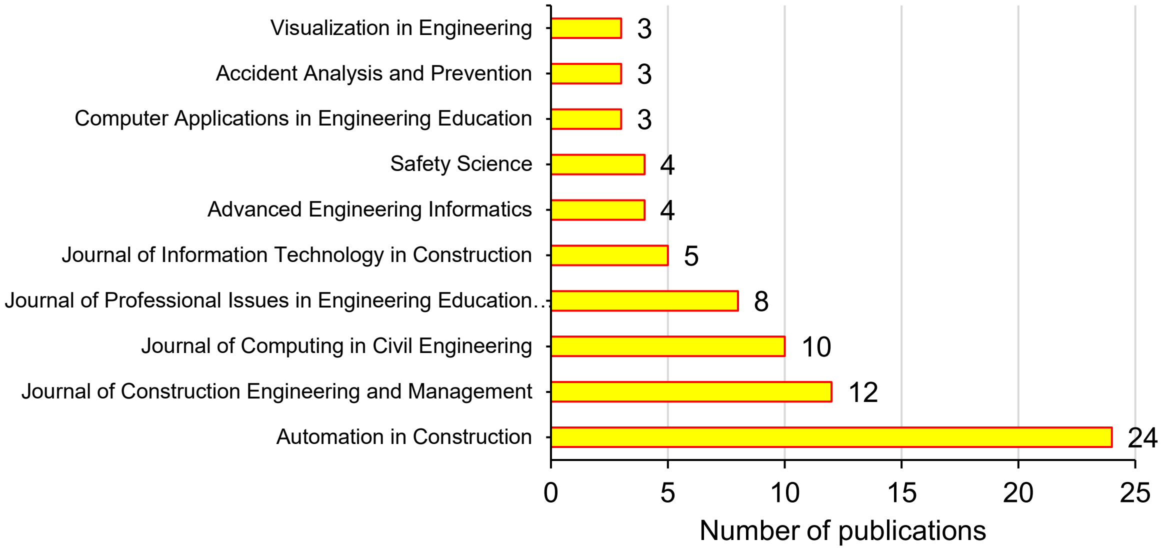

Figure 7. Journals with more publications in the field.

Based on the 250 publications analysed, six different types of XR technologies have been adopted: Non-immersive VR (Desktop-based VR), Immersive Virtual Reality (VR), Game-based VR, BIM-enabled VR, Augmented Reality (AR) and Mixed Reality (MR) (Figure 8 and Appendix I). These technologies are consistent with findings of a network map (Figure 9) that identifies four conceptual clusters. The bold keywords of the first cluster are "Simulation system", "Key technology", and "Robot". For the second cluster, the keywords "Construction site", "Training environment", and "BIM" are highlighted. The distinguished keywords of the third cluster are "Safety", "Construction industry", and "Safety training". Finally, the last cluster is more aligned with "Questionnaire", "Training program", and "Mixed reality".

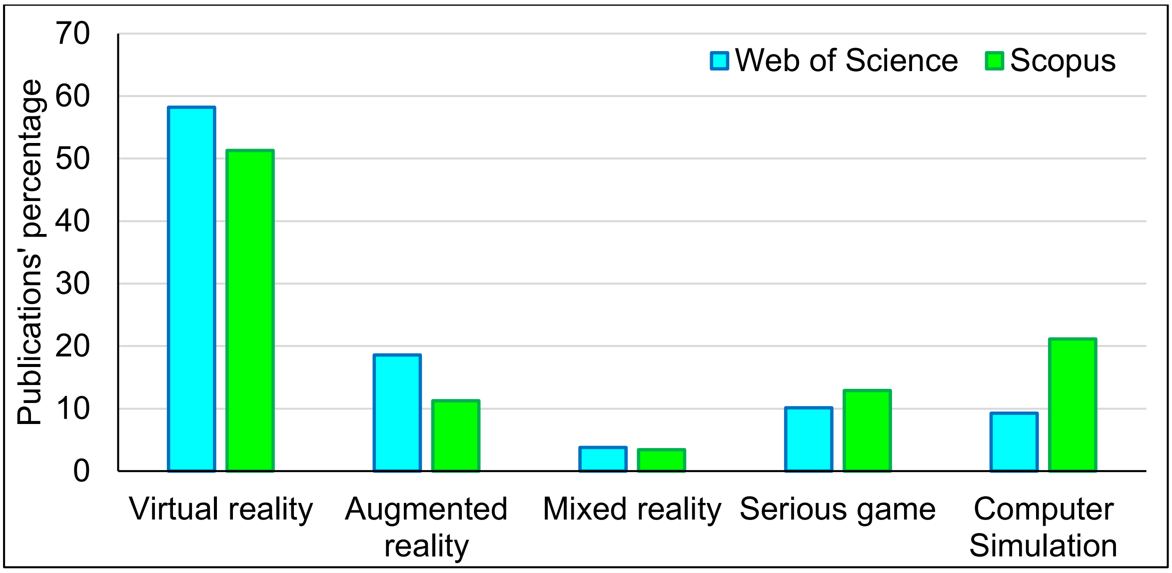

Figure 8. The number of publications based on XR types.

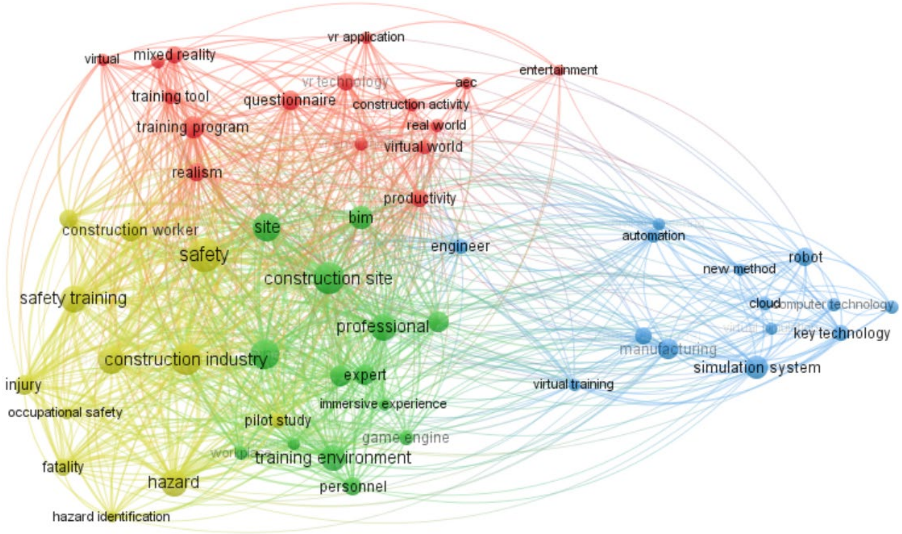

Figure 9. Network map of the collected papers.

Based on the overall literature review, the adoption and implementation of each XR technology in the architecture, engineering, and construction (AEC) sectors are described in the following subsections.

2.1.1 Non-immersive VR (Desktop-based VR)

Desktop-based VR is the most regularly used VR technology in AEC in the initial steps, using only a simple computer monitor as the platform for virtual tasks. Without having any supportive tracking equipment, this technology represents a 3D virtual environment on a desktop screen (Rezazadeh et al., 2011). It depends on the users' perception and spatial capabilities to feel what occurs around them by using keyboards and mouses as well as moving by "walkthrough" in the non-immersive environment (P. Wang et al., 2018). As such, it is a relatively inexpensive technology compared with others.

For maintenance engineering training, Sawhney et al. (2000) proposed an interactive construction management learning system (ICMLS) as well as an object-oriented based on desktop VR-enabled system (V-REALISM). ICMLS was used to solve the disconnections between training and real-life onsite processes using construction equipment and techniques. In addition, the geometrical models were created employing Computer-Aided Design (CAD) that facilitates the operations and navigations of models in the virtual context. The findings indicate education costs decline when using desktop-based VR. Further, the ICMLS can provide the requirements of onsite construction, which can later be embedded into AEC, based on Mawlana et al. (2015). The desktop-based VR development is approximately steady. Besides, recent developments focus on 3D computer models and virtual laboratories to raise students' comprehension and motives (Glick et al., 2012; Vergara et al., 2017). In a study performed by Su et al. (2013), the computer-based VR technology was used to train construction excavators' control skills to compare the design efficiencies of the education schedules. To do this experiment, commercially available Simlog's Hydraulic Excavator Personal Simulator was used on a desktop computer with joystick controls and an LCD monitor. Likewise, Fogarty et al. (2018) used a desktop computer screen to extend non-immersive VR conditions supported by a handheld system and a head-mounted device. They wanted to aid trainee comprehension of complex spatial arrangements in structural engineering. Considering the optimal portability and affordability, non-immersive VR is more practical than immersive VR.

2.1.2 Immersive VR

VR is related to computer technologies that use software to simulate users' physical presence in an immersive environment by producing realistic sounds, images, and other emotions. The idea of VR came in the 1990s when numerous industries were affected by games; the first immersive human-computer interaction (HCI) mock-up, Man-Machine Graphical Communication System was developed. The second wave of VR arrived after 2005. This technology was successfully used in several fields: travel, military, marketing, communication, business, entertainment, education and training, construction, architecture, design, mental health, medicine, and engineering. Recently, quick advancement in user interfaces, software products, components, and devices throughout the world means many principal players in e-commerce and manufacturing have adopted these technologies (Alizadehsalehi et al., 2020).

To separate users from the physical environment via an immersive world, immersive VR needs specific hardware, including sensor gloves and a head-mounted device (HMD). Spatial immersion is built by creating sounds, images, and other virtual scenarios where users can feel the virtual environment as "real" and "authentic" (P. Wang et al., 2018). Studies suggest VR technologies can be effective in site layout optimisation of construction projects (Muhammad et al., 2020), project schedule control (Fu & Liu, 2018), and construction safety training (Li et al., 2018). VR technologies can also:

- promote better collaboration among stakeholders (Alizadehsalehi et al., 2019a)
- assist collaborative decision-making process (Du et al., 2018)
- represent building geometry in such a way that users can comprehend a project effectively and achieve better design decisions (Bille et al., 2014)
- recognise design problems (Romano et al., 2019)
- facilitate a better perception of complex designs (Sutcliffe et al., 2019).

Waly and Thabet (2003) proposed a typical presentation of immersive VR technology – the Cave Automatic Virtual Environment (CAVE). The CAVE is a multi-person collaborative, four-sided display (left, right, front, and down), room-sized, 3D video, and audio environment. 3D models are produced in software like AutoCAD, and then converted into the CAVE. In addition, several sensors can be attached to the accessories of the participants, such as suits and gloves, to offer real-time feedback (Burns & Ausburn, 2007; Hutchinson & Kuester, 2004; Kaufmann et al., 2000).

Because of the real-time capacities, immersive VR technology is thought to be beneficial over desktop-based VR systems. Virginia Polytechnic Institute and State University (Setareh et al., 2005) developed another famous immersive VR system – the virtual structural analysis program (VSAP). The principal advantage of this system is to comprehend the structural behaviours of buildings in a virtual context. Developing an immersive portal interface is the major contribution of VSAP because conventional immersive interfaces have a higher cost. In the case of the desktop interface, it has low cost, but it sacrifices the quality. An adjusted Virginia Tech CAVE (VT-CAVE) was consequently extended with a 3 m × 3 m × 2.75 m cubic room. This system is proved to be efficient in terms of usability.

To present immersive sensations to users, immersive VR technology can have more supportive control devices, particularly tracking tools for interactions, including motion tracking devices and game controllers. They are ordinarily set to demonstrate and identify the movements of materials in the virtual context. Sacks and Pikas (2013) used a 3D immersive VR power-wall for construction safety training. The framework included three rear-projection screens, and it is an open arrangement of a three-sided CAVE that serves 3D stereo projection using active glasses. The students used XBOX controllers and head tracking systems (Setareh et al., 2005) tracked by eight cameras installed on the tops of screens. The conclusions indicate VR-based training is more efficient in keeping the concentration of users and giving students a control measure in the environment. P. Wang et al. (2018) and C. Wang et al. (2018) used Unity 5.3.4 and Autodesk 3D Studio Max Design 2015 to provide the head-mounted display/360-degree display of the immersive system in VR-embedded BIM immersive systems. Teizer et al. (2013) combined real-time location tracking and 3D immersive data visualisation methods in education and training contexts of existing construction ironworkers. 3D models of the existing training facilities created in Sketchup were converted into 3D Studio Max data and then brought into the real-time 3D virtual context software. Every student was equipped with an Ultra-Wideband (UWB) tag to track and record their locations in real-time. Operation and safety information can be visualised and monitored to increase workers' situational awareness using real-time feedback. Involving all trainees through data visualisation in an immersive VR context can enhance training efficiencies. Hence, the real-time feeling in an immersive VR system can provide more benefits than a desktop-based VR system.

2.1.3 Game-based VR

Game-based VR technology uses immersive influence, enables users to travel 3D interactive contexts in real-time (Sampaio et al., 2013), and improves users' interactions. 3D game technology aims to magnify users' interactions using the combination of network, interactive, visual, and multi-user operating technologies. As game-based education, this technology can improve interaction and collaboration among trainees via useful materials that are like real-life operations (Dickinson et al., 2011; Li et al., 2012b; Lin et al., 2011; Nikolic et al., 2015).

Game-based VR concentrates more on the interactions of game objects instead of focusing only on the immersive influence. For instance, a physics simulation module in a game engine can accurately express collision reactions. To lessen the complexity of the detection process, simplified ray tracing and collision boundary methods are used in 3D game-based VR technology. For this, game objects should be established by both their collision boundaries and geometric properties. For complicated objects like construction cranes and excavators, it diminishes the complexity and can make "collision detection" computationally more comfortable.

Guo et al. (2012) proposed a game-based safety learning system in an online platform that permits students to use input devices, including game controllers, mouses, and keyboards, to do virtual activities, such as material delivery and equipment operation. The main benefit of this system is the possibility of repeated examinations at a low cost. For instance, various schedules and techniques to operate a piece of equipment can be examined using a game-based system. During the examination, the potential problems consisting of health and safety concerns can be recognised.

Dickinson et al. (2011) introduced a game-based learning platform to manage construction defects. The virtual elements are generated by close-to-reality defect scenarios and Revit Architecture represented with the support of Linden Scripting Language. In this platform, trainees are taught defects knowledge. They are then asked to distinguish defects and potential activities causing defects in different scenarios. Concerning the performance and interactivity, the test results are positive.

Le et al. (2015) proposed a collaborative/social VR system on a Second Life (SL) 3D virtual world framework, introduced by Linden lab, to intensify training processes and construction safety education. SL in-world tool-prim simulation, Autodesk Revit Architecture, and Maya can support the 3D safety simulations and designs. Moreover, non-immersive VR presents facilities to serve game engines in safety education. According to an existing game engine, Li et al. (2012a) produced a multi-user virtual safety learning system for dismantling tower cranes. This can facilitate prototyping and robust development and is an innovative approach to interactive 3D content creation.

These game-based techniques facilitate self-assessment by giving penalty scores and incentives for non-optimal and optimal solutions, respectively (Goedert et al., 2011). Game-based VR systems assure real-time collaborations by permitting team-based problem-solving supporting different participant roles, including project manager, superintendent, and field engineer. Consequently, users can communicate with their instructors and peers within the virtual context to obtain safety knowledge and promote their cooperative and collaborative skills.

2.1.4 BIM-enabled reality technology

Regardless of the various research on adapting VR systems, the levels of details of VR content have not been recognised. A mixture of the features of 3D BIM models and VR techniques exposes students to immersive, self-motivating, and engaging content that induces experiential learning and virtual interaction (Le et al., 2015). BIM is associated with generating and applying 3D objects comprising related properties information (Gheisari et al., 2016; Song et al., 2018). The associated properties information is especially concerned with essential data needed throughout the whole life cycle of practical building projects – design, planning, construction, operation, and maintenance stages. In addition, BIM-enabled VR systems rely on models, highlighting the connections and data binding behind other VR systems, to simulate construction and operations processes.

Visualisation is one of the most significant features of BIM (Wang et al., 2014). BIM data can be accessible for users in an immersive visualisation context which can analyse parameters such as material type and cost of generating efficient building design in real time. By analysing the design features, all components of BIM models, including architecture, structure, mechanical, electrical, and plumbing, can be investigated in a more detailed fashion. For instance, BIM-enabled VR systems enable users to transfer building designs into 3D virtual environments with all associated building information. It can allow for BIM models in virtual contexts without the limitations of inspecting 2D drawings and design spaces. Tools such as Autodesk Revit Live enable students to simply shift from traditional 2D drawing designs to BIM-based VR interactive contexts. It can keep the integrity of building management data in the virtual context before beginning the construction, which can aid comprehension about how design components will come together. One of the greatest benefits of BIM-based VR systems is the potential to reveal real-time changes. Xie et al. (2011) claimed the conventional VR models generated by VRML might have problems dealing with real-time information. The compatibility problem may induce such issues.

Additionally, many tools have been introduced to help with decision making. For instance, Woodward and Hakkaraine (2011) proposed a software system to merge 3D models with schedule information to monitor onsite construction work. Park et al. (2016) produced an interactive building anatomy modelling (IBAM) system which enables trainees to work in a VR context with building components. A question-and-answer scenario embedded in games can be blended to improve the training experience. P. Wang et al. (2018) and C. Wang et al. (2018) introduced a VR-embedded BIM immersive system for quantity surveying education and practice, consisting of a non-immersive system (Desktop VR) and an immersive system

(360-degree display/ head-mounted display). The proposed VR system was developed to enhance the efficiency and accuracy of calculating quantities from BIM. To do so, trainees can imagine hidden features and contexts that are not attainable in traditional lecture-based teaching systems.

2.1.5 Augmented reality (AR) technology

AR uses sensory technologies to provide live direct or indirect prospects of a physical context with augmented virtual information. The sensory technologies can provide graphics, videos, and sounds. Importantly, VR and AR are different visualisation technologies. Based on the assessment conducted by Fonseca et al. (2014), AR allows users to interact with objects (consisting of changing the scales, positions, and other properties) that match correctly into the real environment in comparison with a VR environment. For AR, no occlusion appears between real-world and computer-generated contents. Mostly, the computer-generated content can only be viewed from tablet and smartphone devices. The tablet- and phone-based AR devices (iPads) represent very restricted immersive viewing experiences. Further, the functional variety of wearable AR devices is limited such as Google Glass and Meta 2 (with a 90-degree field of view) which have been produced for the digital and information objects being added on top of real-world contexts.

There are four kinds of AR: 1) maker-based AR (scanning a QR code); 2) location-based AR (combined with GPS for mapping directions); 3) projection-based AR (projecting artificial light onto real-world surfaces); and 4) superimposition-based AR (an AR-type like the IKEA app that sets virtual furniture in real environments) (Alizadehsalehi et al., 2019b).

Several studies show AR technology can present new interaction opportunities and encourage active student participation (Ayer et al., 2016; Behzadan & Kamat, 2013; Shirazi & Behzadan, 2015a). For instance, Chen et al. (2011) applied ARToolKit for developing an AR model to improve trainers' abilities to perceive spatial objects. As AR models can project various 3D models in actual contexts, they can intensify students' education (Chi et al., 2013). Further, since mobile devices are more suitable for learning, multiple applications have been suggested to set AR in mobile devices. For instance, Williams et al. (2015) employed a mobile AR (MAR) context to teach users about context-awareness.

Additionally, Shirazi and Behzadan (2015b) proposed a mobile context-aware AR platform for undergraduate courses in construction engineering. In this platform, static extendable mark-up language is used to define the content, and JavaScript logic is used to determine the interactions of objects. Moreover, Kim et al. (2012) developed an AR-based tool for optimising construction processes during settling equipment operation. This tool improves visualisation from the operator's perspective and surrounding restrictions can be distinguished.

Rankohi and Waugh (2013) carried out a statistical review of recent AR research in AEC. The review results revealed project managers and field workers are interested in using standalone desktop AR and non-immersive technologies through the construction stage, principally to monitor processes and identify defective works. Shin and Dunston (2008) introduced a full map to show AR applications in industrial construction. They reported eight work duties – including strategising, commenting, supervision, coordination, inspection, positioning, excavation, and layout – might benefit from AR. Behzadan (2008) performed a broad survey of using the AR technology in construction management applications. Further, Rankohi and Waugh (2013) classified AR applications used in the AEC industry into seven classes – safety or inspection, education or learning, progress monitoring, information evaluation or access, information modelling, collaboration or communication, and simulation or visualisation.

2.1.6 Mixed reality (MR)

MR is a semi-immersive spectrum that mixes the best perspectives of AR and VR. It varies between absolute "reality" as observed by users without computer-intervention, and absolute "virtual reality" which includes a computer-generated context without any interaction of users with the physical world (Milgram & Colquhoun, 1999). While the AR experience facilitates the digital content to be added "on top" of the real world, the VR immerses trainees in digital environments disconnected from the real world, and MR allows the digital content to interact with the real world (Chalhoub & Ayer, 2018; Wang & Dunston, 2008). MR faces boundaries and barriers that provide the interactivity level. The flexibility makes MR more commercial and less strange than its cousins.

Nonetheless, because of the small number of available devices on the market, the product classification is somewhat loosely explained. For instance, the Windows Mixed Reality headsets (produced by vendors such as Samsung, Lenovo, Dell, Acer, and HP) are the only VR headsets that do not permit users to view through Head Mounted Devices (HMDs). This means it is not possible to see an overlapping scene of the digital content interacting with the physical contexts.

There are numerous potential applications of MR in the AEC industry, particularly applications including the physical/virtual contexts interacting/overlapping feature on construction sites (Chalhoub & Ayer, 2018). DAQRI Smart Glasses, Magic Leap One, and Microsoft HoloLens are the most well-known MR headsets available. Alizadehsalehi et al. (2019a) explained how the performance and fertility of construction processes could be enhanced at all phases by applying of MR with other techniques and technologies. For MR usage and adoption, using rapidly changing technologies, software, and devices makes the AEC industry predictions notably hard. Cheng et al. (2020) reviewed the use of MR from the viewpoints of multiuser collaboration, data storage- transfer, user interface, and the precision of spatial registration.

Moreover, constant and quick advancement in MR software and tools improves performance and makes MR more efficient each year. The immersive hardware tools change quickly. Future hardware advancements should enhance user convenience and visual realism. MR technology is accepted as an excellent tool for improving construction processes and project designs because of the fast growth of MR appropriation and implementation.

A common element of XR is the hardware development combined with software applications. Current XR devices use combinations of liquid crystal display (LCD) and light emitting diode (LED) panels paired with optical lenses to provide visuals to the wearer. At the simplest level, the XR devices allow the user to visualise 3D information linked to an environment that is either virtual (VR) or real (AR). We will discuss the hardware in greater detail, highlighting the importance of physical movement with different scales of spatial environments.

We should acknowledge there has been significant work around augmentation via audio. In contrast, our other nonvisual senses – touch, smell, and taste – have received comparatively less attention. Overall, most interest in XR development to date has focused on the visual domain. While we are interested in multimodal XR developments, this section introduces categories for XR devices based on the increasing distance of the device from the eye (Figure 10).

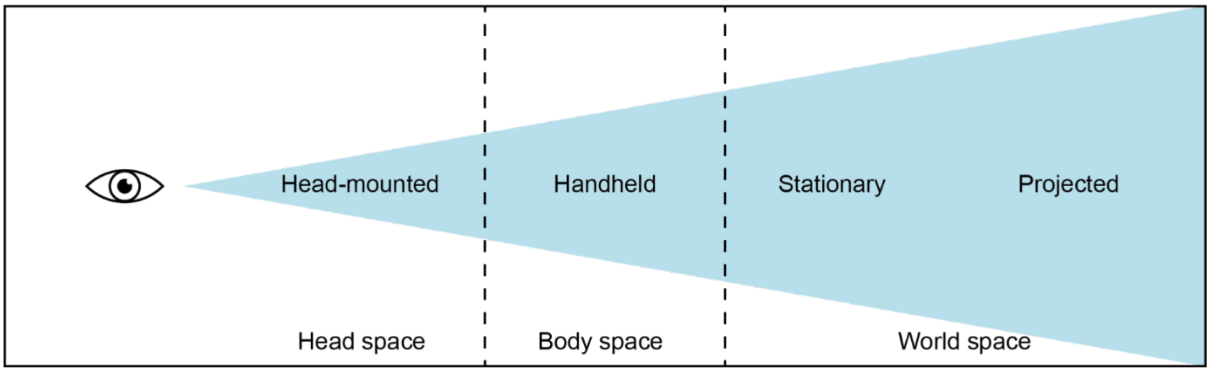

Figure 10. XR devices can be categorised according to the distance from eye to display (Reproduced from (Schmalstieg & Höllerer, 2016).

2.1.7 Head space

Head-mounted devices (HMDs) and near-eye displays are probably the most prominent class. Using an HMD in an AR setup goes back to Sutherland's seminal work in the late 1960s. Engineering devices to be worn on the head is a complex endeavour (Kiyokawa, 2007). They must be unobtrusive and comfortable, yet they should provide the highest possible viewing quality.

Ergonomics are critical for near-eye devices. An HMD should be as lightweight as possible, particularly to be suitable for more extended periods of use. Apart from the electronic components and optics, the casing or mounting will largely determine the weight.

2.1.8 Body space

The rapid development of smartphones and tablet computers has made hand-held devices the most popular platform for AR to date. Given the camera is usually pointing straight away from the back of the device, it is generally necessary to hold the device at least at chest height. This pose can lead to fatigue within a relatively short period; in addition, it may be challenging to keep the device still enough in this pose to observe all the details.

Being able to store the device away when not needed is a mixed blessing. On the one hand, it bypasses the need to wear the device, such as on the head permanently. On the other hand, it impacts immediacy because taking a hand-held display out of the pocket may be too cumbersome for short-term usage. A hand-held device accommodates both the display and the camera in one shell; the transformation from display to the camera can be pre-calibrated. In most cases, tracking the device's pose in the world will be performed through the camera.

A recent development proposes user-perspective rather than device-perspective displays. That is, rather than showing an augmented video image purely from the camera perspective, the user is also tracked. With smartphones and tablets being key enablers for context-sensitive or "situated" computing, it is no wonder hand-held platforms are driving the vision of XR as a game-changing user interface to the physical world.

2.1.9 World space

Stationary and projected devices have some obvious benefits, such as their social function as group communication enablers. Some of these devices include *Desktop Displays, Virtual Mirror, Virtual Showcase, Window & Portal Displays,* and *Projected Displays*. With the use of projectors in the FogScreen example, we entered the realm of projected displays. As projectors become increasingly powerful and affordable, they are no longer unique to traditional application scenarios (movie theatres, classrooms, and auditoriums). These devices found uses in personal setups and novel public events involving special effects and interactive narratives onto outdoor architecture, such as building facades or factory halls. The latter applications, which are sometimes referred to as *digital projection mapping*, exemplify the concept of spatial augmentation.

Devices must be able to combine virtual and real, which can occur in different modalities. Most XR research has been pursued in the visual domain, but there has also been a research focus on audio. Our other human senses, particularly haptics, play an increasing role in realistic experiences. State-of-the-art XR experiences focus on visual engagement, supported by spatial audio.

Many immersion parameters are essential for delivering a useful XR experience, including ‘ocularity’, the field of view, brightness and contrast, occlusion, latency, focus mechanism, resolution, and the size and comfort of the display technology.

We should highlight in categorising XR devices based on their placement relative to the user – on the head, on the body, and in the environment (world) – no single type of device or category can accommodate every possible use case. Through their sheer ubiquity and economies of scale, hand-held devices brought the idea and potential of XR technologies to everybody’s awareness. Head-worn devices, via advanced technological and ergonomic innovations, might represent the next wave of XR but are still vying for widespread acceptance. Particularly, light-field displays represent a promising new approach, taking advantage of contemporary micro-displays and their increasing high pixel resolutions.

2.1.10 Games engines

The development workflows for making XR applications usually use methods similar to the production of computer games while using some specialised variations or plugins. In the games industry, multiple types of software development kits (SDK) exist, but Unity and Unreal Engine are the most widely adopted in the Australian games development market (A. Chauhan, 2021). Unity and Unreal Engine are examples of *game engines* or *development platforms* that form part of the core software architecture that developers use to create and run their games. A game engine provides functions for:

- rendering 2D or 3D graphics (via a render engine)
- a physics engine
- user input (controllers or sensors)
- collision-detection or collision response
- sound
- animation
- scripting
- streaming and networking
- artificial intelligence.

Games engines are configurable for a broad spectrum of games or applications and often provide capabilities and tools to connect to other software or platforms such as webpages or third party software (Unity, 2021). The functionality, customisation and support for developers in Unity and Unreal Engine has pushed these two engines to the front of the marketplace for development. Both SDKs have adopted a free-to-use but payment of royalties for any games sales – Unreal beginning this payment model in 2015, and Unity Technologies adopting a similar model in 2018. The parent companies for Unity (Unity Technologies) and Unreal Engine (Epic) also promoted free use of their software for universities and schools outside of commercial interests. The success of games such as *Fortnite* and *PlayerUnknown's Battlegrounds* (using Unreal Engine), and *Kerbal Space Program* and *Hearthstone* (using Unity) have contributed to an industry that is estimated to be worth USD200 billion in 2021 (Accenture, 2021).

This project decided to complement the literature review with a market analysis to identify the current available XR technologies for construction training and learning in Australia.

2.2 Market analysis on current available XR technologies for training and learning

2.2.1 Main market share players for training VR headsets

By 2022, the AR and VR market is expected to grow to $209.2 billion, with a projection that over 30 million AR/VR headsets will be sold annually by the end of 2023 (Statistia, 2021). There are over 171 million VR users worldwide. In 2019 alone, 14 million AR and VR devices were sold, and 70% of VR headset owners have bought a game on it. In 2020 Oculus (Quest and Quest 2) dominated the list of top five XR devices (Figure 11).

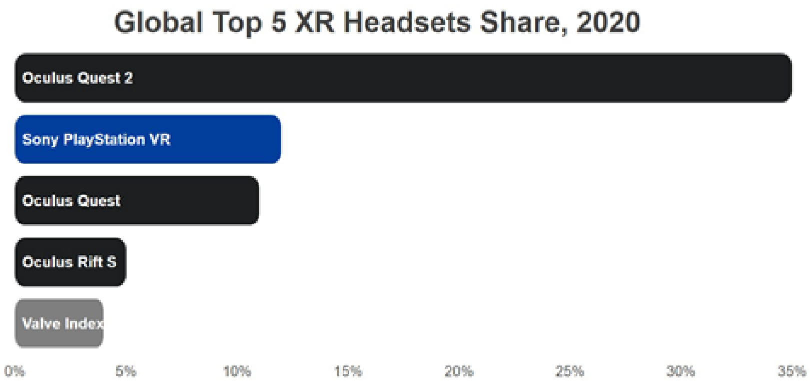

Figure 11. Global Top 5 XR Headsets Share, Q4 2020 (Reproduced from Counterpoint, 2021 referenced in (K. Chauhan, 2021)).

In 2021 Q1, the Oculus Quest 2 (Facebook's VR headset) dominated the market with a 75% share. Standalone headsets represent 85% of the AR/VR space (see Figure 12).

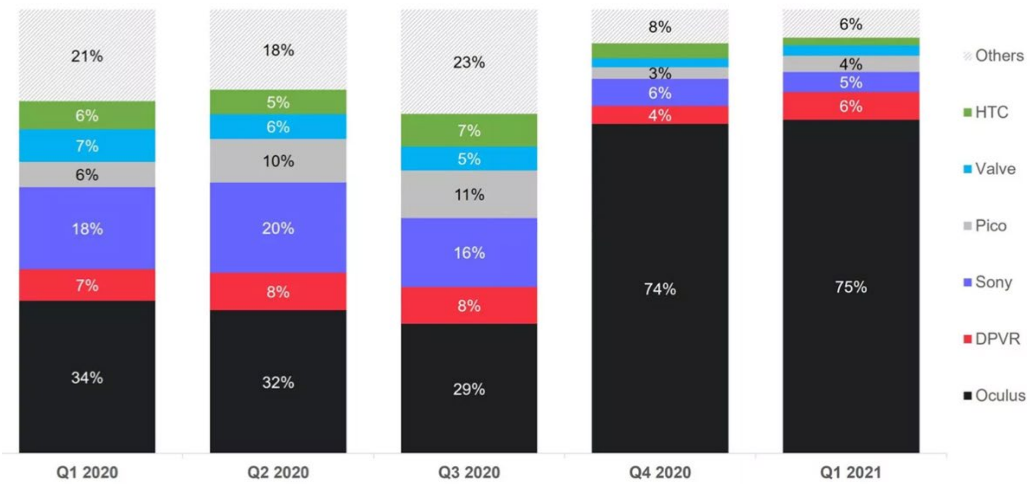

Figure 12. Global Top XR (VR & AR) Brands' Shipment Share, Q1 2021 (Reproduced from Counterpoint, 2021 referenced in (K. Chauhan, 2021)).

VR has been applied heavily in the health care sector, as a replacement for pharmacotherapy in drug design, pharmacist education, patient counselling, and behaviour modification in the medical industry. Other roles include nano and microsurgery.

Other industries such as aerospace, military, gaming and retail are also taking advantage of the VR growth potential. Figure 13 below shows the projected VR growth rate. HMDs are used rapidly in the defence sector, such as in ground-based applications (e.g. simulator and soldier applications) and airborne applications. In the 2019-20 Australian budget, the defence budget accounted for 1.9% of gross domestic product, creating a vast market opportunity for HMDs in the military and defence sector (Mordor Intellegence, 2021).

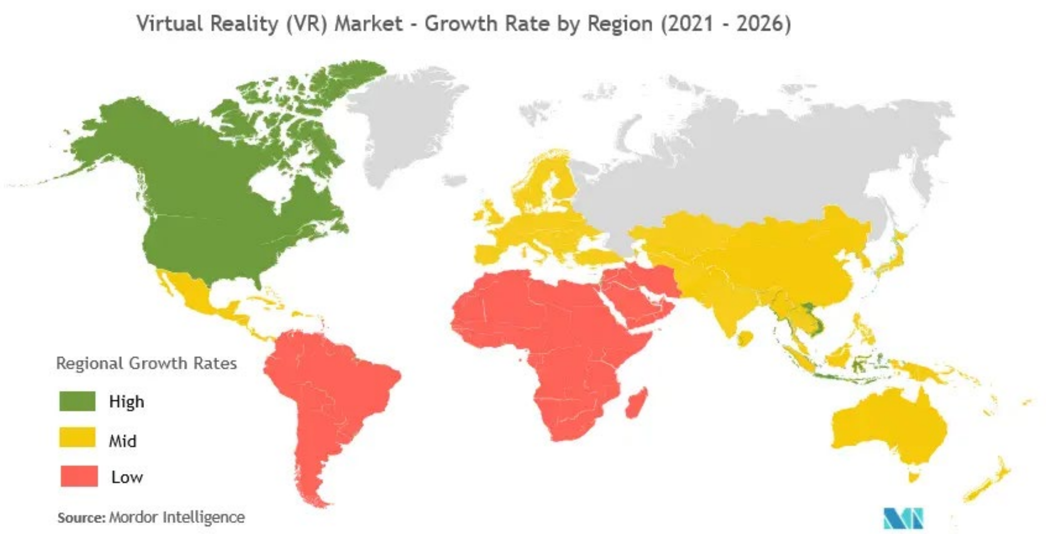

Figure 13. VR Market Projected Growth Rate (Reproduced from (Mordor Intellegence, 2021)).

2.2.2 Market survey findings

A market survey was conducted to identify technology and service providers in the market who offer third party development of XR (VR, AR, and MR) training materials to bodies such as Holmesglen. The survey took place between August and September 2021 and targeted Australian-based XR software developers. Multiple methods of identifying and analysing the XR development companies included via:

- social media, including LinkedIn, Twitter
- search engines, such as Google, Bing
- VR networking events and groups
- contacting industry representatives
- contacting XR development companies.

Overall, the survey identified 77 development companies that advertised or had demonstrated examples of producing XR applications (Appendix II). From the 77 XR capable companies, those with extensive experience in creating training applications, specifically in different areas of the VET market, are shown in Table 2.

Most training applications used Unity to create their training applications, and VR headsets were the most applied technology. Many of the companies surveyed had capabilities and experience in producing AR applications hand-held devices. Only one company (Snobal) publicly demonstrated experience in developing AR headsets (e.g., HoloLens).

A few development companies had experience with Unreal Engine. Some companies revealed their assets were produced 'in-house' by 3D designers and animators using software such as Blender, Houdini, Substance Painter and Maya. None of the companies revealed if they used specific coding languages. Cost of development for applications varied based on the scope of work, development platform for delivery, and timeline of the projects. None of the companies listed were willing to reveal their production costs, but all the companies preferred to develop to an agreed fixed price for the quoted scope of work rather than a subscription-based cost model.

Table 2. XR application development companies with VTO software experience.

PROVIDER NAME URL	LOCATION	STATE	TYPE		DEVICES		DEVELOPMENT PLATFORM					TRAINING TYPE	TRAINING COURSE
			VR	AR	HMD	Hand-held	Unity	Unreal	Web	iOS	Android		
emergeWorlds https://emergeworlds.com/vr-training	Brisbane	QLD	X		X		X		X	X	X	Ambulance and First Aid training	VR: First Aid Training
Real Serious Games https://realseriousgames.com/	Brisbane	QLD	X		X HTC Oculus		X					Mining Engineering Construction Industry Training	VR: Reading Drawings Site Hazard Walk Risk & Safety Plans & Specifications Confined Space Virtual Excavation
Exner Education (*collaboration with Real Serious Games) https://www.exner.com.au/	Melbourne	VIC	X		X HTC Oculus		X					Construction Industry Training Transport Training	VR: MTA Training Cert IV in Building and Construction
Augmented Reality Experts https://www.augmentedrealityexperts.com.au/applications/	Melbourne	VIC	X	X	X	X	X		X	X	X	Workplace Training	Safety Training Workplace Training
Chaos Theory https://www.chaostheorygames.com/australian-serious-game-developer	Sydney	NSW	X	X	X HTC Oculus	X	X		X	X	X	Advertising Entertainment Medical Aviation Health and Safety Other Training	Simulation and Training Experiences
Maxart https://www.maxart.com.au/case-studies	Brisbane	QLD	X	X	X	X	X	X				Vehicle Driving Simulation Mechanic Training Sports Ethics Training Healthcare Training	VR: In-Vehicle Driving Simulator Service Technician Training
Raytracer https://raytracer.co/	Brisbane	QLD	X		X			X				Astronaut Simulation Training Military Applications	VR: Training for Defence
7DX https://7dx.co/	Sydney	NSW										Multiple Staff Training Specific Industry-Related Training	VR: Induction and Safety Training
ThoroughTec Simulation	Perth	WA	X	X	X CAVE		X					Vehicle Driving Simulation Mining Equipment Training	VR: Vehicle Training

https://www.thoroughtec.co m/												Fire Safety Equipment Training	Induction and Safety Training Military Equipment Training
ACHIEVR http://www.achievr.zone/	Sydney	NSW	X	X	X HTC Oculus	X	X					Crane Operator Training Operational Efficiency in Food Manufacturing Firefighting Training Fast Food Fryer Safety Signalman Training	Fire Fighting Training Fast Food Fryer Safety C6 Mobile Crane Trainer Dogger/Signalman Trainer
LiminalVR https://liminalvr.com/training -simulation/	Melbourne	VIC	X		X		X					Fire Safety Training Industry Training Agriculture Skill Training and more...	VR: Training to promote positive change and Mental Wellbeing in the workplace
Staples https://www.staplesvr.com/	Melbourne Sydney	VIC, NSW	X		X HTC		X		X	X	X	Aircraft Maintenance Training Truck Driver Training Healthcare Simulation Civil Engineering Staff Onboarding	VR: Defence Force Training Student Training Tool (Medical) Aviation Training Simulator Truck Driver Training Forensic Training AR: Allergic Asthma Training
Isonomic https://www.isonomic.org/	Sydney	NSW	X	X	X	X	X					Specialised Industrial Training Construction Training	Simulation and Training Experiences
Snobal https://snobal.io/	Melbourne?	VIC			X	X	X	?	X	X	X	Design Collaboration Industry Training	XR: Solution for design collaboration & testing Solution for stakeholder & customer engagement Solution for smart asset planning & maintenance Solutions for training, workplace learning and education
Bondi Labs https://www.bondilabs.com/	Melbourne		X		X		X	X				Customs Quarantine Training Healthcare Engineering Oil and Gas Technical Training	Biosecurity Occupational Health & Safety Engineering Health

As noticed from the overall literature review, several industries have tried XR technologies in various disciplines for different purposes, such as technical training, management training, and field trips. Commonly, XR technologies are adopted as part of the training because they enable staff to be trained without limits or danger to respond to situations impossible to reproduce in the real world. In the case of the VET sector, XR technologies can be used to engage trainees in the learning process by enabling deeper and more authentic learning experiences. In other words, XR technologies diversify learning environments and promote meaningful learning by creating a more realistic understanding of learning phenomena. Technological solutions can help trainees better understand and reflect on their own learning. Overall, innovative vocational education based on XR technologies can provide initial skilling and help trainees retrain as jobs and industries evolve, including in response to economic and technological change. The most tangible outcome of immersive learning for the VET sector is that trainees gain a deep understanding of core subjects while simultaneously developing cross-cutting skills, such as digital and problem-solving skills, to thrive in further education, training or work.

However, each XR technology adoption requires unique considerations in the VET sector. For example, some challenges that immersive learning could bring into the VET sector are security issues, intangible roadmap, considerable investment, lack of experience, trainee concerns, low collaboration, lack of specialised staff, multidisciplinary teams, and increased dependence on IT. Therefore, immersive learning demands that trainers rigorously evaluate which XR technology is more appropriate for a learning experience. For this reason, this research proposes a framework of decision-making criteria to select appropriate XR technologies for specific skill training. The initial version of this decision-making criteria was done through a literature review with the main findings summarised below.

2.3 Decision-making criteria for choosing the XR technologies in VET

Different studies have investigated the effectiveness of various immersive technologies for training purposes. However, as discussed earlier, the literature and research on this topic have mainly focused on describing the technical development of the tools and simulations as trials or demonstrations (Rankohi & Waugh, 2013). These studies ignored critical aspects of the implementation process that will ensure the adoption, acceptance, routinisation, and infusion (Venkatesh & Bala, 2008) of XR technologies in the training delivery process in educational institutions. This lack is even more severe in the VET system because while institutions have promoted research development primarily to target immersive learning strategies in safety training programs (e.g., Bourhim & Cherkaoui, 2020; Li et al., 2012a; Li et al., 2018), little is known about the implementation process and the effect of contextual factors that influence this process. As a solution, this research analysed the most representative immersive learning cases in the construction industry to fill the gap in the VET context and recommends how to adapt conventional teaching approaches to enhance teaching (P. Wang et al., 2018) and the training process towards digital and work-related skills.

For this, an in-depth literature review to develop an initial framework was done to summarise training, technology and institutional factors that affect the educational-technology integration of XR technologies in VET. In addition, case studies that investigated the effectiveness of various XR technologies for training purposes or documented the decision-making process were collected from the literature. The objective was to summarise the most important factors to select the appropriate XR technology for specific skill training in the construction industry. In short, seven publications were analysed (Bourhim & Cherkaoui, 2020; Dhalmahapatra et al., 2021; Janaćković et al., 2018; Kim et al., 2021; Kurilovas &

Vinogradova, 2016; Try et al., 2021; Zhang et al., 2019). Additional literature on the adoption of XR technologies at the industry level (Davila Delgado et al., 2020) and of general learning technologies (Liu et al., 2020; Sailer et al., 2021b) was reviewed to complement and construct the first version of the decision -making criteria.

2.3.1 First case study: Immersive VR- based safety simulator

Dhalmahapatra et al. (2021) investigated a safety training simulator designed by VR to operate electric overhead cranes. To do so, they considered three main groups of effective criteria: a) presence analysis, b) system usability, and c) simulation sickness:

a) Presence analysis

The presence analysis surveys immersion and involvement perception of users in virtual contexts (Witmer et al., 2005). The presence questionnaire, proposed by Witmer and Singer (1998), considers users' sensation of being in the virtual contexts. It denotes the realisation degree of users to be immersed in the virtual context rather than in the immediate physical context. Four parameters influence user presence: 1) user engagement, 2) immersion levels, 3) visual accuracy, and 4) interface quality of the context. The four-level education assessment model concentrates on four factors for training evaluation, including learning, behaviour, reaction, and results. The presence criterion considered in this study principally focused on the above-mentioned education assessment model. For this main criterion, four sub-criteria can be regarded as 1) sensory, 2) control, 3) distraction, and 4) realism. These sub-criteria specify the quality of the immersive technologies as well as subsequent training procedures. For each sub-criterion, the following themes can be considered:

- Sensory: sensory modality, environmental richness, multimodal presentation, consistency of multimodal information, and active search
- Control: control degree, control immediacy, forecast, and control mode
- Distraction: isolation and selective attention
- Realism: scene reality, information consistency, and experience meaningfulness.

b) Usability analysis

The system usability is based on users' expectations of the system. The system usability scale was initially introduced as a "quick and dirty" scale for applying after usability examinations on systems like VT100 Terminal ("Green-Screen") applications. This scale is independent of the type of technology and has several purposes: hardware testing, consumer software, websites, cell phones, immersive technologies, and even the yellow pages. Various parameters influence this analysis, including learning rate, comfort degree, satisfaction, and complexity of the education procedure. System usability examines users' adaptability with the system from the viewpoints of convenience and ease of use (Chalil Madathil & Greenstein, 2017; Hou et al., 2017). In the present study, two sub-criteria were considered for this main criterion: 1) operation comfort and 2) learning comfort. Each of these sub-criteria focuses on the following themes:

- Operation comfort: system complexity, problem-solving nature, task complexity, and operational complexity
- Learning comfort: training, comfortability, clues/information, and satisfaction with the learning process.

c) Sickness analysis.

Simulation sickness is usually defined as the discomfort felt by trainees during or after using immersive technologies (Deb et al., 2017; Kim et al., 2018). Technology developers must consider the probability of simulation sickness when creating virtual environments. If the virtual environments are not produced accurately, it might cause the rejection of immersive technologies. It differs from movement sickness because it can be induced by the visual perceptions of motions and not only by actual movements. Simulation sickness can include three main sub-criteria:

- Nausea is associated with trainees' distress related to gastrointestinal disorders consisting of increased salivation, burping, and stomach upset.
- Oculomotor disturbances are attributed to visual distresses, including headaches, eyestrain, and blurred vision.
- Disorientations are attributed to vestibular disturbances consisting of dizziness and vertigo.

2.3.2 Second case study: Evaluation of a VR mine safety training system

Zhang et al. (2019) evaluated the use of VR for mine safety training systems. For this, they used five main criteria for the evaluation:

a) Engine: The XR engine is mainly used to process user-entered data, perform calculations, and output calculation results (usually computer graphics) to the user. The VR engine determines the motion, deformation, visual effects, etc., of the objects in the training scenes:
    - Universality: the ability to support various I/O devices and operating platforms
    - Efficiency: to have better performance and graphics quality under the same computing power
    - Physics simulation: to simulate realistic physical movements
    - Multiplayer interaction: to meet the requirements of multi-person coordination.

b) I/O devices: The I/O devices are the most influential factor for the XR system because the user interacts with the system directly through the I/O devices. Different I/O devices can bring different degrees of immersion to the user, and the level of immersion is one of the most critical factors determining the experience of the XR system:
    - Natural interaction: mainly the natural degree of interaction of the input device
    - Immersion: how much immersive experience the user get
    - Accuracy: ensures the user's human-computer interaction intent is accurately captured and presented by the input/output device.

c) Software: Software is a crucial factor influencing the comprehensive evaluation of XR systems. I/O devices represent the hardware characteristics of a VR training system, while software design and development represent the software characteristics. Therefore, the software development of an excellent XR training system integrates the I/O devices interaction ability under the framework of the selected XR engine, based on fully considering the training task requirements to be completed and the user's (trainee) characteristics:

- Realism: mainly refers to the graphics quality and physical authenticity of the training system, for example, to obtain better scene simulation effects
- Complexity of interaction: simplicity, intuitiveness, interaction efficiency of the training system
- User data recording: to record the user data that can be used to evaluate the user training effect and other aspects
- System freedom: the degree of freedom that the software supports the user to perform. A higher degree of freedom means that the system can show a wider range of scenarios.

d) Task: The task in the XR training system can determine the personnel who attend the training and the content of the activity. The purpose and scope of system development can be clarified by defining the system task clearly:
   - Type: according to outcomes, learning can be divided into knowledge learning, skill learning, attitude, and motivation learning
   - Specification: it is essential to ensure the specification of tasks during the training process. For example, in an equipment training scenario, the equipment being operated in the virtual environment should act as similarly as possible as in the real world.
   - Decomposition: when conducting a specific task training, the task could be decomposed into specific steps and actions with detailed criteria, and combined with the trainee's actual actions and movements recorded during the training, the errors can be calculated by comparing the task criteria and actual behaviour to obtain the trainee's performance during the training
   - Cognitive load: the complexity and the presentation style of the tasks need to be reasonable. The trainee should be under a proper cognitive load; otherwise, it will reduce the efficiency (cognitive load too low) or the training's effectiveness (cognitive load too high).

e) User: For the user component of the XR training system, previous research has shown various factors of the user must also be considered:
   - Personal situation: factors such as age, gender, education background, etc., will affect the acceptance of new things, new methods, the ability and willingness to learn new things, etc.
   - Experience: the training experience will affect the understanding and attention on the training content and will affect the results of the training at last
   - Physiological and psychological status: the degree of fatigue, the attitude towards training, etc., will affect the effectiveness of the training.

2.3.3 Third case study: AR in safety education and training

Janaćković et al. (2018) assessed the applications of AR in occupational safety training and education with the following criteria:

a) Technical:
   - Reliability

- Availability
- Meantime between failures
- Meantime between maintenance/repair
- Frequency of maintenance
- Infrastructure costs
- Maintenance costs
- Quality/reality of the display/presentation
- Proposed working conditions
- Usability

b) Human:
- Personal desire to use modern technologies
- Employee skills index
- Compliance degree with work procedures
- Degree of employee innovations
- Employee satisfaction index
- The number of errors and omissions
- Communication and reporting skills index
- The effectiveness level of training programs
- Teamwork level of employees
- The percentage of employees with corresponding training

c) Organisational:
- Percentage of employees trained for the use of AR equipment
- Resource and training management efficiency
- Share of working activities covered with adequate AR training and education
- The average value of years of employees' experience
- Percentage of jobs requiring special formal training
- The average number of hours of training of employees during the year
- The number of instructions for using equipment for employees
- The number of problems identified during the inspections and analysis of equipment or working conditions

d) External:
- Level of AR technology
- Level of implemented legal procedures
- Competitiveness level
- The number of implemented voluntary standards
- The degree of company networking
- The number of available instructional databases
- The number of available funds.

2.3.4 Fourth case study: Military training based on the VR of Army using AHP method

Kim et al. (2021) considered the taxonomy presented by Anderson et al. (2001) for measuring the educational effectiveness when implementing VR include in military training:

a) Learning effects:
- Interest: the degree to which fun or concern is induced
- Immersion: the degree to which you concentrate intensely when learning
- Understanding: the degree to which a problem is understood and solved

b) Equipment effects:
    - Reality: the degree to which training reflects the actual situation
    - Safety: the degree of freedom from risks or accidents caused by fear or carelessness when using the equipment
    - Availability: the degree of freedom from equipment damage and aging.

2.3.5 Fifth case study: Quality evaluation of distance learning courses (DLC) using virtual learning environments

Kurilovas & Vinogradova (2016) used the following factors for the quality assessment of virtual learning courses:

a) Internal quality (General) criteria:
    - Overall architecture and implementation:
        i. Scalability
        ii. Modularity (of the architecture)
        iii. Possibility of multiple installations on a single platform
        iv. Reasonable performance optimisations
        v. Look and feel is configurable
        vi. Security
        vii. Modular authentication
        viii. Robustness and stability
        ix. Installation, dependencies, and portability
    - Interoperability:
        i. Integration is straightforward
        ii. VLE standard support
    - Internationalisation and localisation:
        i. Localisable user interface
        ii. Localisation to relevant languages
        iii. Unicode text editing and storage
        iv. Time zones and date localisation
        v. Alternative language support
    - Accessibility:
        i. Text only navigation support
        ii. Scalable fonts and graphics

b) Quality in use (Adaptation) criteria:
    - Adaptability (facilities to customise to suit the institution's needs):
        i. Language
        ii. Design
    - Personalisation aspects (facilities of each user to their view of the platform)
    - Extensibility:
        i. Good programming style
        ii. Availability of a documented API
    - Adaptivity (automatic adaptation to the individual user's needs):
        i. Personal annotations of the content parts
        ii. Automatically adapted content.

2.3.6 Sixth case study: Choosing the optimal engine for VR safety training

Bourhim & Cherkaoui (2020) aimed to develop a training tool to incorporate new standards and codes related to fire evacuations. To do this, they considered the following criteria:

a) Fidelity: the extent to which the virtual environment matches the real world:
    - Audio-visual fidelity:
        i. Rendering: special effects, shadows, lighting, and texturing
        ii. Animation
        iii. Sound
    - Functional fidelity:
        i. Scripting
        ii. Supported AI technologies
        iii. Physics

b) Composability: the reusability of content created and its efficiency in importing and using data from common or proprietary sources:
    - Import/export
    - Developer toolkits

c) Accessibility: support possibility to develop the contents from developers to users' perspectives:
    - Learning curve
    - Documentation and support
    - Licensing
    - Cost

d) Networking: support possibility in large-scale communities or a social element

e) Heterogeneity: support possibility to deploy in a wide range of hardware and software platforms.

2.3.7 Seventh case study: Online education based on VR in a civil engineering unit

Try et al. (2021) presented a case study of VR-aided learning (VRAL) in a civil engineering laboratory to solve COVID constraints. The criteria that influenced the selection of the best learning-aid technologies were:

a) Interactivity: For 'interactive problem-solving and learning', this factor is used to consider which training services can present better practical and theoretical learning environments for trainees during the training process.
b) Accessibility: This factor measures the accessibility of training services considering time and place suitability for trainees.
c) Cognitive interest: For stimulating trainees to be involved in the training process, this factor is used to consider which of the training services has more potential in catching trainees' interest and stimulating them to be engaged in the training tasks.
d) Ease of understanding content: This factor is used to calculate which training service is more proficient for providing training content that is obvious and easily understandable.
e) Support for education: This factor is used to assess which training service is more capable and efficient in assisting students in training and obtaining the training aims.

2.3.8 The initial version of decision-making criteria to select the appropriate XR technology in the VET sector

From the analysis of the case studies described above, decision-making factors were grouped into training, technology, and institutional factors. According to Dhalmahapatra et al. (2021), decision-making criteria should integrate factors affecting the simulation and training in technology development and task development. Regarding training factors, it was decided to include presence factors (Dhalmahapatra et al., 2021) that measure the perception of involvement and immersion (Kim et al., 2021) of trainees with the virtual or physical environment. Additionally, in agreement with Zhang et al. (2019), task factors were integrated, determining the characteristics and features of learning activities such as task type, specification, and decomposition. To complement this group, we incorporate the effectiveness factors as proposed by Clayton et al. (1998) and Liu et al. (2020), such as the trainee involvement speed and the ease of adoption that regulate how effective the learning experience is compared with the expectations of the trainees and trainers.

In most cases, the technology factors were analysed to incorporate specifications regarding the engine, software, the I/O devices and technical factors, in line with Zhang et al. (2019). Engine and software factors comprise the universality as "the ability to support various I/O devices and operating platforms" (Zhang et al, 2019, p. 344) and physics simulation and manipulation, which is attributed to realistic physical movement (Zhang et al, 2019), controlling the pace, and collecting objects during the simulation. Further, these factors are related to what Bourhim & Cherkaoui (2020, p. 957) called 'composability' to refer to "the reusability of content created within a 3D GE (game engine) and also its efficiency to import and use data from common or proprietary sources". On the other hand, I/O device factors refer to the hardware features that influence the trainee's interaction with the system (Zhang et al, 2019) such as weight, handle requirements, power, battery limitations, etc. Finally, the technical factors concern qualities that will alter the experience of trainees in the learning activities like reliability (Janaćković et al., 2018) and sickness, which has been proven as one of the main factors that influence the deficiency of immersive learning because of trainees' discomfort (Dhalmahapatra et al., 2021).

In addition to these training and technology factors, institutional factors were included consistent with Janaćković et al. (2018). These are economic, social, and operational considerations framed as part of the organisational structure (Liu et al., 2020; Sailer et al., 2021) that could influence the adoption of immersive learning in an organisation or institution. Economic factors concern the cost and logistical outlook for the adoption and sustainable implementation of new technology, such as the upfront and ongoing expenses (Ghobadi & Sepasgozar, 2020) and the space requirements (Davila Delgado et al., 2020). The social factors deal with the stakeholders' perception and acceptance of the technology that may affect the implementation. The operational factors influence the viability of the immersive technology implementation in accordance with the current institutional available resources and the integration with current existing teaching practices (i.e., suitability of technology and infrastructure and availability of technical support (Sailer et al., 2021)). These operational factors become crucial because one of the main barriers to adopting XR technologies in the construction industry is the staff lack of skill/expertise (Badamasi et al., 2021). In this group, one of the most critical factors advocated in the literature is the availability of standards (Davila Delgado et al., 2020) and governmental regulations that facilitate the workflow process between disciplines and the data exchange between software.

In short, this research presents the literature review as a foundation to compile the most important criteria to consider in selecting appropriate XR technology for specific vocational training in the building construction industry. Construction training and education have been implementing XR technologies to promote different learning purposes (Appendix I).

Nevertheless, previous work only focused on higher education or safety training neglecting characteristics that affect adoption in the VET sector. Thus, this research proposed developing a Delphi study conducted with VET experts to offer a decision-making process to select appropriate XR technology for the specific skill training in the building construction industry. A Delphi study is a research method approach that looks for consensus of experts' individual opinions about complex topics. It was decided to undertake a Delphi study because diverse groups participated in this research as part of a project developed within Building 4.0 CRC, an industry-led research initiative co-funded by the Australian Government. The findings of this scoping study are expected to provide insight into the adoption of immersive learning technologies in construction vocational training.

3. RESEARCH DESIGN

The Delphi method aims to achieve a consensus in expert opinions using multiple interactions or rounds of data collection and analysis (Alaloul et al., 2015). This method was selected because it uses context-dependent knowledge, supported by expert opinions and expertise, to understand a phenomenon influenced by "subjective judgements" (Grisham, 2009, p. 114). In this work, this aspect was crucial because little is known about the decision-making process at the organisational level, especially in the VET sector. Delphi study is particularly useful in complex situations where stakeholders interact (Grisham, 2009). This is crucial in our study since our participants all worked in the VET sector, but their roles varied very significantly at each organisation (i.e., leadership, academics, professional staff, IT developers or students). Thus, they could have different interests in adopting XR technologies in the training delivery process.

Acknowledging the nature of our research problem and participants and considering the COVID restrictions set in Australia during the project timeline, it was decided to follow an 'online Delphi form' (Alaloul et al., 2015). This means the Delphi process should be undertaken with the aid of an 'online' platform to achieve online consensus between experts, who are selected based on research questions (Alaloul et al., 2015). The 'online' form also influenced the research design explained below.

To develop the Delphi method, we followed the steps proposed by Grisham (2009), as can be observed in Figure 14. The first step was identifying the research problem concerning the crucial criteria in a decision-making process to select appropriate XR technology for the specific skill training in the building construction industry.

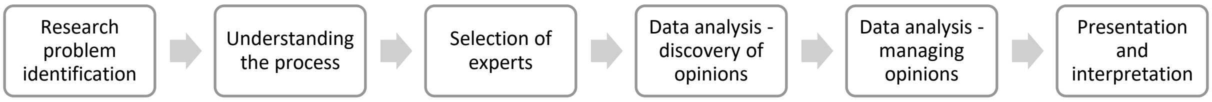

Figure 14. Delphi process adopted (Reproduced from Grisham (2009)).

The second step: 'understanding the process' is perhaps the most critical in the Delphi method because it is when the data collection is planned, together with the interview or questionnaire design. We used Alaloul et al.'s (2015) recommendation to design each round because they developed Delphi method considerations exclusively for the construction industry. According to their suggestion, the first round for 'online' forms of the Delphi method should be opened. As a result, the first round involved three 90-min focus groups with each participant group (i.e., leadership, academic/professional staff, and IT developers) to understand general challenges and opportunities, identify focus areas, discuss and collectively rank the first version of the decision-making criteria, and develop questionnaires for the second round (Hsu & Sandford, 2007). Each focus group started with an overview of the research aim and methods, followed by a semi-structured group discussion on a list of categorised topics and the factors in an initial draft of the decision-making criteria.

The two project industry partners nominated experts. Ten participants were involved in at least one round, fully compliant with Cochran (1983) advice. Table 3 describes the professional profile of the experts. All participants had experience, to different extents, in the planning, development, or implementation of XR technologies for learning and training activities in the VET sector. Only two students were willing to participate in the research; thus, it was decided to undertake individual phone interviews for the first round following the same kind of questions proposed for the focus group to gain perspectives about the receiving end of the technology.

Table 3. Characteristics of the participants who participated in the Delphi process.

Category	Number of participants
Type of organisation	Education / Training institute (12), XR company (1), Product Analyst with experience in Education (1)
Role	Leadership (7), Teaching or Technology Support Staff (4), Resource Developer (3)
Years of experience	0 – 5 years (3), 6 – 10 years (4), 11 – 15 years (4), 16 –20 years (2), more than 20 years (1)
Level of familiarity with education/training subject matters	Not at all (0), Slightly (1), Moderately (2), Very (4), Extremely (7)
Level of familiarity with XR technologies	Not at all (0), Slightly (3), Moderately (3), Very (5), Extremely (3)

The data analysis involved qualitative approaches for the first round and quantitative approaches for rounds 2 and 3. Therefore, focus groups were analysed by a deductive qualitative content approach (Elo & Kyngäs, 2008), which means the factors obtained from the literature review were used to manage and code the manifest content of the data (Elo & Kyngäs, 2008). Zoom transcripts of each focus group were imported to NVIVO to code and manage the data. For rounds 2 and 3, the questionnaire aimed to identify “areas of disagreement and agreement” (Hsu & Sandford, 2007, p. 3) in the importance of the factors using a five-point Likert scale. The consensus was measured by the standard variation of the importance rating, which was provided to participants in Round 3, where they could re-judge their opinions and justify perceptions (Alaloul et al., 2015). The following section describes the design and findings of each of the rounds.

4. DELPHI STUDY: ROUND-BY-ROUND FINDINGS

The research team adopts the Delphi approach to collect and analyse the input from domain experts and eventually to arrive at a group opinion towards a set of key topics. This approach comprises one round of focus groups and two rounds of questionnaire surveys. This section reports the design of the focus group and questionnaire rounds and summarises their key findings.

4.1 Round 1 – Focus Group

4.1.1 Overview

Technology adoption is a complex process involving decisions and feedback from a range of stakeholders. To understand the considerations and priorities of different stakeholders, we formed three focus groups with participants in the roles of leadership, teaching staff, and resource developers. Each focus group started with an overview of the research aim and methods, followed by a semi-structured group discussion of a list of categorised topics and the initial factors in a draft of decision-making criteria.

The participants were nominated by the two project industry partners, Holmesglen Institute and the Master Builders Association Victoria (MBAV). All participants had experiences, to different extents, with the planning, development, or implementation of XR technologies for learning and training activities in the VET sector. Focus groups #1 and #3 comprise participants from the two industry partner organisations who have roles in either leadership and/or teaching staff. Focus group #2 consists of participants from multiple companies who are in the role of resource developers. In addition to the three focus groups, we conducted two one-on-one interviews with trainees from Holmesglen Institute to gain perspectives about the receiving end of the technology.

4.1.2 Key findings

In the focus groups, a list of categorised topics was used to guide the discussion, including 1) current teaching and learning practices, 2) XR integration, 3) XR use cases and lessons learnt, and 4) XR content development. This section presents the key findings under each of these topics summarised based on the discussion in the three focus groups.

Current teaching and learning practices

This section covers the current state of teaching and learning practices in the VET sector. This includes teaching and assessment methods, associated tools, and observed teaching challenges.

- Teaching methods

Most training is still done using traditional methods (i.e., in-person classroom teaching), and more recently, some classrooms have moved online due to COVID-19. While XR use has been limited, the construction industry is experiencing a big global push to implement more immersive and experiential teaching methods using XR applications.

- Assessment methods

Assessment methods vary but usually consists of a form of continuous assessment throughout a course. It was mostly done in a traditional, written assessment format, but digital assessment methods are becoming more popular.

- Tools

Traditional teaching aids (e.g., blackboard, paper-back material) were used the most, but there is a move to online Learning Management Systems (LMS).

- Teaching challenges

Current teaching challenges include training packages being outdated, some training material being boring, and inconsistent assessment methods within organisations.

XR integration

This section covers the extent of XR integration within the companies providing VET services. This includes the source of content, type and use of data collected from XR activities and XR engagement strategies.

- XR content development source

Development of XR material is done in-house where possible but has sometimes been outsourced to external parties. In-house development is preferred due to simpler logistics, and it allows for people with the relevant knowledge to be involved in development. However, this is not always possible due to the lack of development capability.

- XR training data collection

Data is generally collected in the form of 1) observed trainee performance, 2) recorded training sessions, 3) task completion rates and 4) trainee feedback surveys. When considering XR, the data is collected in a broad sense and is less focused on the actual ability of the trainees to perform specific tasks.

- XR training data analysis

The collected data is used to 1) verify and improve training delivery in terms of consistency and suitability of technology and 2) as evidence of engagement for course requirements. There is generally more emphasis on the variance of human factors during a session rather than computer-based simulations, which are consistent when designed well.

- XR engagement strategies

XR use is an entirely optional component and not forced onto trainees. Instead, most trainees were found to engage with XR technology out of curiosity.

XR use cases and lessons learnt

This section covers the current applications of XR in VET, including some examples of hardware, reasons and cases for use, as well as the benefits and issues with XR.

- Current XR tools
    - 360-degree technology
    - VR head-mounted display

  - VR parabolic screen
  - AR head-mounted display
  - AR phone application
  - MR head-mounted display
- Current XR use cases
  - Workplace or task simulation: XR is mainly used to immerse a trainee in a simulated environment where they can conduct a specific task repeatedly without being exposed to actual occupational health and safety (OHS) risks.
  - Assessment and enhanced course delivery: Trainees are assessed on a few units of competency, based on how they act in a simulated scenario in an XR environment. However, while there is a formal process for assessing a trainee, the main purpose of XR is to enhance course delivery by providing an engaging experience for the trainee and helping them achieve learning outcomes.
  - The 'wow' factor: XR technology is also used to add a 'wow' factor to attract and impress stakeholders in the construction sector.
- Perceived benefits of XR use:
  - Reduced human error
  - Reduced OHS risks
  - Improved trainee skill development and knowledge retention
  - Improved trainee attention, engagement, motivation
  - Collaborative interaction and learning
  - Improved course marketing
  - Reduced need for unnecessary travel
- Observed issues in XR use and integration:
  - Training factors
    - Age and industry experience level
    - Aversion to change (i.e., comfortable with existing methods)
    - Lack of technical expertise or familiarity
    - Social anxiety
    - Language skills
    - Poor or unclear training effectiveness
    - Difficulty in training task repeatability and training consistency
  - Technology factors
    - Portability of equipment
    - Power and battery limitations
    - Sickness factor from technology use (i.e., nausea, motion sickness)
    - Technology evolution (i.e., hardware becomes obsolete quickly)
    - Lack of one-for-all solution (i.e., each activity is unique and handled with different methods or technology)
  - Institutional factors
    - Large upfront and ongoing costs, including:
      - Upfront – hardware purchase, course material development/purchase costs
      - Ongoing – maintenance of hardware and software, updating course material, educating teaching staff on XR technology use
      - In certain courses where the trainee is required to purchase the equipment, the hardware price exceeds the cost of the learning
    - Different views inter- and/or intra-organisation, including knowledge gaps and differences of opinion:

        - between teaching staff and XR material development staff (i.e., XR developers may lack knowledge of in-class activities)
        - between subject experts
        - between different departments
        - between worker unions and businesses
    - Logistics issues in implementation, which are often overlooked:
        - providing a facility with sufficient equipment and space
        - timetabling hours for competent teaching staff and several students within limited course timeframes
    - Data security, storage, and ownership
    - Availability of technical and educational support for both trainers and trainees
    - Availability of standards or best practices for XR integration and development
    - Evolving requirement for employability (e.g., qualification requirements, digital skills).

XR content development

This section covers the key considerations when developing XR content and a brief look into the processes behind developing XR content.

- XR development considerations:
    - Training task goal/outcome: The goal is the primary development consideration. Importantly, the goal of the XR development could influence most, if not all, other development considerations/factors such as task instructions, hardware characteristics, etc.
    - Costs and budget: From a training material developer's perspective, the cost is a significant consideration in two areas:
        - Accessibility for clients in terms of how much the customer can afford to spend on training programs
        - Long-term commercial viability and sustainability in terms of 1) maintenance of hardware and software, 2) updating course material, 3) ability to reuse content.
    - Choice of hardware and associated support and maintenance: The hardware choice should reflect the most suitable device for achieving the goal of a particular training activity and consider the logistics behind its selection (e.g., availability of technical expertise, costs, etc.).
    - Natural interaction and intuitiveness requirement: The handling and controls that come with the choice of hardware should be teachable but also feel natural and intuitive with respect to the training task that is simulated in XR.
    - Training task content and target audience: The content should be suitable for being represented in XR and tailored towards the target audience's demography, experience level, etc.
    - Immersion and realism requirement: The content should be sufficiently immersive and feel real enough for the associated task.
    - Trainee's level of enjoyment and engagement: The experience should be developed in a way such that a trainee enjoys the experience.
    - Flexibility of development platform or engine: This includes the development platform's available features, which includes special effects (e.g., weather, lighting), ease of use, and ease of deploying updates.
    - Training task repeatability: The ability of a task to be repeated by the same person and by different people and still achieve the same outcome.

- XR development process: It is suggested that the design and development process for an XR training task is no different to any other instructional design storyboarding process and that XR technology is simply the medium used for delivery. It generally includes the following steps:
    - Framework preparation on task requirements: An overall task framework is set up to determine the requirements of the training task briefly regarding the skill or knowledge gap to be filled.
    - Design of technical content: The technical content to be simulated in XR is then designed around the desired task outcome. This includes identifying gaps in the task's technical brief which can only be addressed with XR and not through normal means. When this is not carefully considered, it has been observed that the XR technology is often made redundant due to the existing barriers to using it.

      It is argued that determining the suitability of simulating activity in XR is often difficult, and a trial-and-error process involving prototype tests is sometimes involved with the target users. Overall, it is about "finding that balance between the best way to convey the information and also the best sort of technology to use to do that".

      In addition to using the feedback from the target users to simulate activity in XR effectively, it is suggested that the knowledge and expertise level of the content developer in that specific task plays a large part in determining the success of the XR content.
    - Choosing an appropriate XR device: The most suitable XR device is selected, with regard to the other development considerations, to achieve the best outcome.

4.2 Rounds 2 and 3– Questionnaires

4.2.1 Overview

After the focus group sessions, participants were requested to take part in two rounds of online follow-up questionnaires. The aim was to reach a consensus on the importance of certain factors when deciding what XR technology should be implemented and how it should be integrated into a VET program.

In the first questionnaire (Q1), participants provided details on their role and personal experience with XR. They also rated a list of factors from the decision-making criteria on a five-point scale of importance ranging from 'Not at all important' to 'Extremely important'. The objectives of Q1 were to:

1) obtain the baseline importance rating for each factor
2) understand the variance among responses from different participants, and
3) determine correlations between participant experience and their factor importance ratings using statistical analysis (i.e., a One-Way Analysis of Variance 95% confidence).

In addition, the participants could suggest improvements to the factors in terms of missing or redundant factors based on their experience.

In the second questionnaire (Q2), participants gave feedback on the 12 factors that did not achieve a satisfactory consensus (SD<1) in Q1. Given the collective results of the factor ratings in Q1, participants re-rated the importance of each of these factors. Participants were asked to elaborate on: 1) why they did or did not change their rating, and 2) why they think there was significant variance in the initial rating done in Q1. Lastly, the participants provided feedback on the improvement suggestions for the factors received in Q1.

All 19 participants from the three focus groups were invited to complete both Q1 and Q2. In the end, Q1 received 14 responses, while Q2 received 10 responses.

4.2.2 Key findings

Questionnaire 1

From Q1, the statistical analysis determined that there was a significant difference in opinion:

- Between Leadership and Teaching/technology staff on the importance of the 'Institutional Infrastructure' factor
- Between participants with an XR familiarity of '2-Slightly' and participants with an XR familiarity of '3-Moderately' or '4-Very' on the 'Simulator sickness' factor
- Between participants with a Training and Teaching familiarity of '3-Moderately' and participants with a Training and Teaching familiarity of '2-Slightly' or '5-Extremely' on the importance of the 'Size of cohort' factor
- Between participants with a Training and Teaching familiarity of '2-Slightly' and participants with a Training and Teaching familiarity of '3-Moderately', '4-Very', or '5-Extremely' on the importance of the 'Interoperability' factor.

Questionnaire 2

From Q2, the new ratings given to the factors had most of them achieve a good consensus (SD<1) apart from the following three factors: 1) Interoperability, 2) Flexibility, and 3) Realism/fidelity. This section compares the ratings for these factors between Q1 and Q2 and investigates the factors with the most change. The average importance rating and standard deviation changes between Q1 and Q2 can be seen in Figure 15 and Table 4.

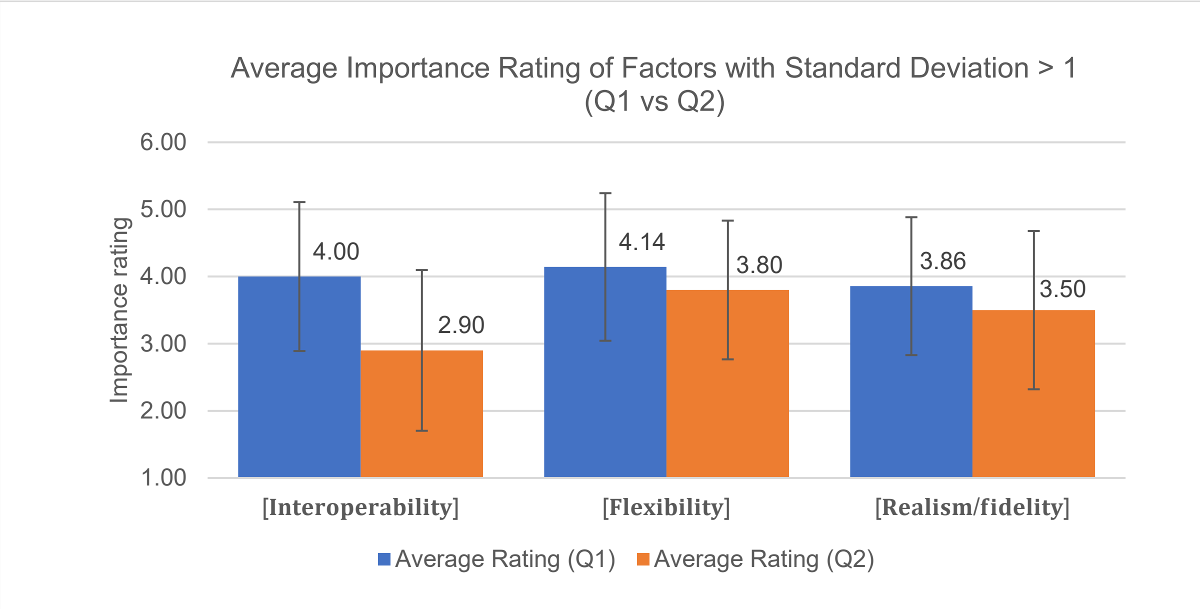

Figure 15. Average Importance Rating of Factors with Standard Deviation > 1 (Q1 vs Q2).

Table 4. Factors with Standard Deviation > 1 after Q2.

Factor	Average Rating		Standard Deviation	
	Q1	Q2	Q1	Q2
[Interoperability]	4.00	2.90	1.11	1.20
[Flexibility]	4.14	3.80	1.10	1.03
[Realism/fidelity]	3.86	3.50	1.03	1.18

- Interoperability – The ability of the XR system to share information and services
  - Participants considered this factor was highly overrated in Q1. Some participants considered it may be important for an XR device to share information (e.g., with a learning management system). However, it is not the most important issue.
  - The top two perceived reasons for variance are ‘Difference in familiarity with XR’ and ‘Difference in familiarity with training and teaching in VET’.
- Flexibility – The ability of the XR system to be used for different training purposes
  - Participants considered this factor was overrated in Q1. They considered it is good practice to have a flexible piece of XR equipment that is easy to use in multiple instances, but a lot of work remains to be done in the area.
  - The top two perceived reasons for variance are ‘Difference in personal role experience’ and ‘Difference in familiarity with training and teaching in VET’.
- Realism/fidelity – Accurate and realistic representation of a person, thing, or situation
  - Participants considered this factor was overrated in Q1. They considered realism and fidelity requirements are dependent on the outcome, and high levels are not always necessary. For instance, in terms of the target audience, professionals would require higher fidelity. Also, less realistic simulations can be used effectively if the main components of the simulation are realistic enough (e.g., environment physics not as important as crane physics in a crane simulator).
  - The top two perceived reasons for variance are ‘Difference in personal role experience’ and ‘Difference in familiarity with XR’.

Overall, the three factors with the biggest rating changes from Q1 to Q2 can be seen in Table 5 below.

Table 5. Factors with the highest rating change from Q1 to Q2.

Factor	Average Rating		Change
	Q1	Q2	
[Interoperability]	4.00	2.90	-1.10
[Power and battery]	3.36	2.80	-0.56
[Realism/fidelity]	3.86	3.50	-0.36

4.3 Overall results

After two rounds of questionnaires, a verified importance rating of each of the factors from the decision-making criteria was obtained. Figure 16 presents the average importance rating and the standard deviation of all factors.

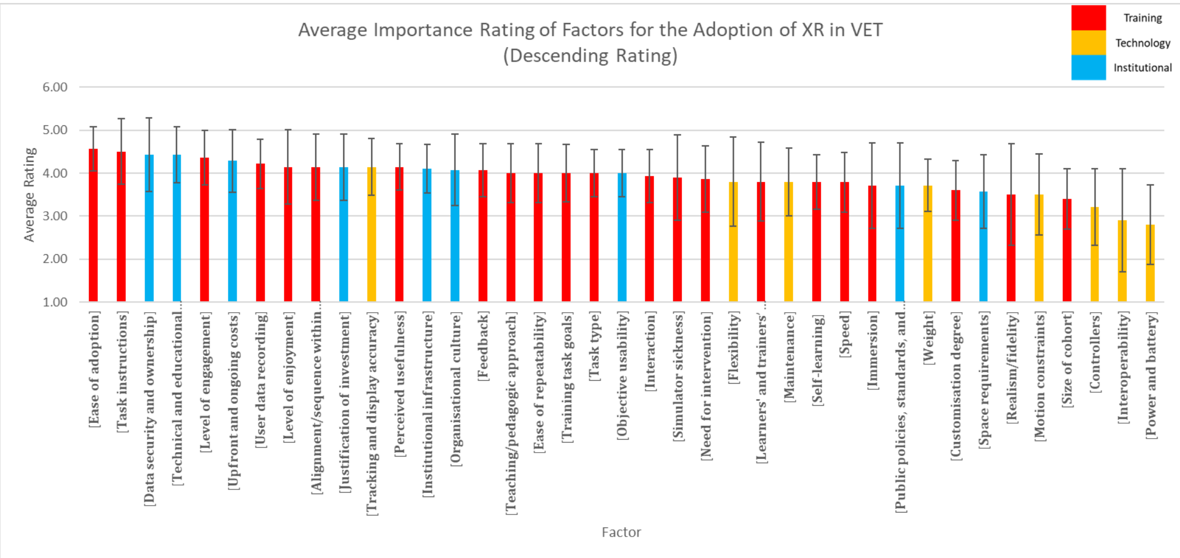

Figure 16. Average importance rating and standard deviation of all factors

As shown, the three most important factors are:

- Ease of adoption – Describes the amount of effort it takes to adopt a targeted training platform.
- Task instructions – Familiarise trainees with the training activity and technology to be used. Determine the role of the trainer during the task.
- Data security and ownership – Determine the owner and the degree to which people can use the data.

On the other hand, the three least important factors are:

- Power and battery – The requirement to charge devices or have them plugged in for continuous use.
- Interoperability – The ability of the XR system to share information and services.

- Controllers – The required use of hands during the use phase, including only one hand-free and both hands-free conditions.

Full tables, as well as charts ranking the factors based on their average importance rating, category, and standard deviation, can be found in Appendix III.

4.4 Factor improvement suggestions

Additional recommendations from Q1 were also discussed in Q2. There was a concern of:

“Dramatic impact on organisations when they begin to adopt at scale – it's quite disruptive and can threaten existing employee roles (put trainers out of work, for example).”

Most participants believe it is crucial to consider the potential disruptions (e.g., job loss) for incorporating XR technology in the teaching approach, trainer support and education, as well as the associated cost and time requirements for implementation. However, some participants firmly believe the technology is not disruptive to the extent that it will replace trainers.

In addition, a consensus towards the importance of factors affecting adoption decision-making was achieved by using the Delphi method. The results obtained from the qualitative analysis at each stage were continuously used to revise and improve the decision-making factors. This resulted in some factors being changed, combined, or removed. Thus, the final version of the decision-making criteria may not reflect the same terms used in this analysis.

5. DISCUSSION

This section describes the most important findings as part of this research:

- the challenges and considerations of using XR technologies in the VET sector identified via the Delphi study
- the final version of the decision-making criteria for selecting XR technologies in construction training
- the workflow process to translate conventional learning into immersive learning
- trainers' skills implications.

5.1 Challenges and considerations of using XR technologies in the VET sector

While benefits of immersive learning have been widely documented in the literature, the Delphi study identified some challenges. These challenges address some of the VET sector's particular features that completely change the process for adopting XR technologies. Using the same categories of decision-making criteria for selecting XR technologies in the VET sector described in section 2.3.8, these challenges and considerations will be divided into training, technological and institutional.

5.1.1 Training challenges and considerations:

- Adoption justification: Trainers and educational providers should evaluate from the beginning the outcomes that they are trying to achieve with XR technologies. This justification ensures the technology supports the learning outcomes integrated into the overall course.
- Strategies of adoption control: Although the XR application is geared towards enhancing the experience and engagement of trainees, the XR application should collect data to evaluate its effectiveness according to the adoption/learning goals.
- XR application goals and storyboarding: It is critical to evaluate the XR application learning goals (i.e., assessment forms or transfer of information) before starting the storyboarding design. Similarly, it is crucial always to check back to the training needs to assess how the storyboarding addresses them.
- Target audience and trainees' professional profile: Most VET sector trainees already have a lot of professional and practical experience. Likewise, they are not young people who are easily open to using technology-based learning.
- Trainees needs: Ensuring the trainees' needs are always met. "The technology needs to support the learning, not lead the learning" (Expert focus group, 2021).
- XR content development: XR content development should be developed by people with the appropriate professional knowledge.

5.1.2 Technological challenges and considerations:

- Technology set-up: Rather than impose the XR application on trainees, giving them the option has shown considerable benefits in terms of curiosity. Trainees should feel confident using the technology; they need to have the chance to try the controllers before completing any task.
- Technology evolution: XR technologies are developed rapidly; hardware may become outdated soon.
- Hardware – commercial decision: Although there is no consensus on the best hardware to be used in the VET sector, its selection depends on the adoption scale. Bring your

own device (BYOD) approach is used on a large scale in contrast to institutions providing technology. Whatever the approach, the simulation should be flexible to be adapted to trainees' needs.
- Complete support of the Learning Management System (LMS): A software application or web-based technology embedded into all the VET courses could facilitate the adoption of XR technologies in the training delivery.
- Maintenance costs: Costs associated with updating the XR content based on learning goals and trainees' needs should be considered.

5.1.3 Institutional challenges and considerations:

- Aversion to change: Most people fear change (i.e., make jobs obsolete, learn new things, etc.). This aspect is critical in trainers who need to feel comfortable using XR technologies and be aware of their benefits for training delivery.
- Fragmented industry: Lack of alignment of interest inter/intra organisation.
- Technology experts and training experts: These two groups of experts should be incorporated in the adoption process to ensure corporate knowledge and culture towards immersive learning.
- Government support: The adoption of XR technologies in the VET sector is not financially viable. Government funding is required to support the technology adoption and restructure VET training.

5.2 Decision-making criteria for XR technologies in construction training

This subsection presents the last version of the decision-making criteria using findings from the literature review and Delphi study:

5.2.1 Training factors

It involves factors that influence the learning experience, such as the trainees' involvement and the trainers' expectations. Additionally, it involves characteristics related to the complexity of the proposed learning and teaching activities.

1. Unit-factors: Determine the suitability of a targeted training platform to be implemented in a unit.
    - Learners and trainers' attributes: Factors such as age, gender, education/ professional background, the attitude/motivation towards training/technology and anxiety to implement changes.
    - Teaching/pedagogic approach: It is a set of principles, beliefs, or ideas about the nature of learning translated into the classroom.
    - Alignment/sequence within other scheduled teaching activities: Sequence with other teaching activities and alignment with different learning outcomes.
    - Size of cohort: Number of students who are educated at the same period.
2. Task factors: Factors that will determine the characteristics and features of learning activities.
    - Training task goals: Learning objectives associated with specific knowledge, skills, and attitudes. Define if the task will be done individually or collaboratively.
    - Task type: It depends on how technology is used by the students themselves and how they are cognitively stimulated and engaged with it. Tasks could be categorised into passive, active, constructive, and interactive activities.
    - Task instructions: Familiarise learners with the training activity and technology to be used. Determine the role of the trainer during the task.

- Customisation degree: Factor that influences the trainer's ability to change and adapt to the training content and process.
- Self-learning: Self-dependency during the learning process by creating a learner-centred system.
- Ease of repeatability: The frequency of use of the training system to achieve a learning outcome without generating fatigue.
- Level of enjoyment: Fun and enjoyment level of an experience.
- Level of engagement: Enthusiasm level and learners' connection when participating in a training process.
- Feedback: Immediate feedback to learners' input and opportunities on debriefing on learning achievement.
- User data recording: Related to the record of user data that can be served to evaluate the user training effect using the XR system.

3. Effectiveness factors: How effective the learning experience is compared with the expectations of the learners and trainers.
   - Speed: The time required to complete the proposed training task in a particular training platform.
   - Objective usability: Referred to as the accomplishment of certain tasks using a targeted training platform.
   - Ease of adoption: Describes the amount of effort it takes to adopt a targeted training platform.
   - Perceived usefulness: The degree to which a trainer believes using technology would enhance their delivery process.
   - Need for intervention: The degree to which critical errors are prevented or the ability to quickly correct errors when learners perform the task.
4. Presence factors: Influence the feeling and learners' perception of being.
   - Immersion: Degree of immersive experience from no immersion towards full immersion. It influences the feeling of presence.
   - Interaction: The communication between a learner and the targeted training platform realised by using input and output devices.
   - Realism/fidelity: Accurate and realistic representation of a person, thing, or situation.
   - Simulator sickness: It can include nausea, oculomotor disturbance, and disorientation experienced in the targeted training platform.

5.2.2 Technology factors

It involves specifications regarding the software and the I/O devices.

1. Engine and software factors: The XR engine is mainly used to process user-entered data, perform calculations and generate results (usually through computer graphics and sounds). The VR engine determines the motion, deformation, and visual effects of the objects in the training scenes. Moreover, the software development of an XR training system is to integrate the I/O devices interaction ability under the framework of the selected XR engine, based on fully considering the training task requirements to be completed and the trainee's characteristics.
   - Interoperability: The ability of the XR system to share information and services.
   - Flexibility: The ability of the XR system to be used for different training purposes.
   - Maintenance: Includes the mean time between failures, mean time between maintenance/repair, and frequency of maintenance for updating/upgrading software and hardware equipment.

2. Input/output devices: Features of the hardware that influence the interaction of the learner with the system.
   - Weight: Weight of the headset, controllers and other accessories that the learner needs to carry.
   - Controllers: The required use of hands during the use phase, including only one hand-free and both hands-free conditions.
   - Motion constraints: Includes the limitations of how the XR system utilises immersion, presence and interaction such as degrees of freedom, tracking range and tethered versus untethered devices.
   - Tracking and display accuracy: The accuracy of the devices in capturing environment data, tracking the user motion and displaying the results to users.
   - Power and battery.

5.2.3 Institutional factors

It involves economic, social, and operational factors to determine the viability of new technologies in an immersive learning approach.

1. Economic factors: The cost and logistical outlook for adopting and sustainable implementation of new technology.
   - Upfront and ongoing costs: Device purchase/maintenance, educator training, VR content development, infrastructure costs, maintenance costs, cost of keeping technology updated, etc.
   - Justification of investment: Full understanding of potential benefits and risks to the business.
   - Space requirements: Cost of space to host the XR activities, networks and power required, etc.
2. Social and operational factors: The stakeholders' perception and acceptance towards the technology that may affect the implementation, including factors that can influence the viability of technology implementation with available resources and workflow integration with existing practices.
   - Public policies, standards, and commitment: Availability of standards and governmental efforts and roadmaps that promote the use of XR in the industry.
   - Organisational culture: Institutional ethos and commitment.
   - Technical and educational support: Availability of technical and educational support for trainers which influences the XR system adoption.
   - Institutional infrastructure: Availability of digital infrastructure and learning management system.
   - Data security and ownership: Determine the owner and the degree to which people can use the data.

In short, these decision-making criteria were summarised in Figure 17, where the three main categories (i.e., training, technology, and institution) are more clearly illustrated.

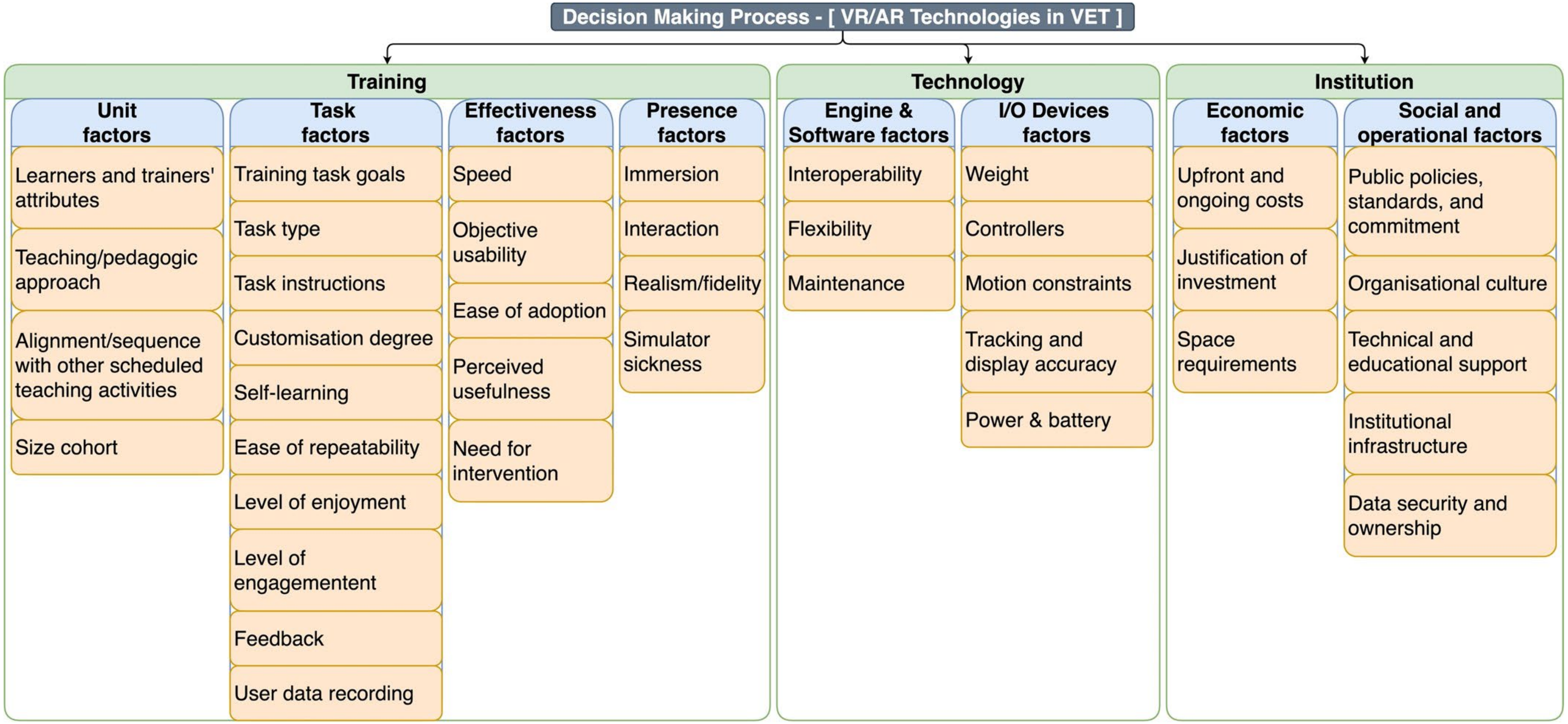

Figure 17. Decision-making criteria for selecting XR technologies in the VET sector.

In short, these decision-making criteria should be used to consider the most important factors that could influence the adoption of XR technologies in construction training. Despite having found a neglected area in the field of XR technologies in the VET sector, Round 1 of the Delphi study helped validate definitions and considerations of the factors identified in the literature review. Moreover, rounds 2 and 3 were targeted to corroborate the importance of the factors based on VET experts' opinions.

VET experts gave more importance to training factors, followed by institutional factors and technology factors. As displayed in Appendix III, most training factors have a higher average rating and a lower standard deviation. 'Realism/fidelity' was the only one that did not reach a consensus (with a standard deviation of 1.18) because, as discussed earlier, higher levels of realism and fidelity are not always desirable. Indeed, the levels of realism and fidelity will depend on the types of tasks performed, the audience profile, etc. Further, some recent studies confirmed the presence factors are also affected by subjective factors such as students' emotional state (Dengel & Mägdefrau, 2019). Therefore, the following step of this research should evaluate the special considerations when defining the realism/fidelity level in XR applications used in construction training.

Institutional factors also were evaluated as very important. In particular, 'Data security and ownership' and 'Technical and educational support' were in the top 5 most important factors (see Appendix III). These factors represent considerations that VET providers must define before starting any XR technology adoption. For instance, an appropriate support system must be available for trainers before starting any pilot application to ensure trainers feel confident using these types of technologies. On the other hand, experts gave a low importance rating to the following institutional factors despite reaching consensus – 'Space requirements' and 'Public policies, standards and commitment'. It is very likely this could have occurred because the availability of policies and standards is not a direct responsibility of educational providers. Instead, these tools should be promoted in collaboration with the government and other sectors to evaluate how standardised approaches could be developed.

Finally, the technology factors were evaluated as less important. This is also consistent with Round 1 findings, where experts highlighted the importance of defining learning outcomes and goals from the beginning of the process. It thus can be suggested that before buying any hardware or software, educational providers should examine the training factors that will help evaluate the effectiveness and viability of adopting XR technologies in construction training programs. Significantly, these results were contemplated to design the workflow process explained above to recommend how to adopt XR technologies effectively in vocational skill training for the building industry.

5.4 Workflow process for translating conventional learning into immersive learning

Although the construction industry, especially with education concerns, has been adopting more digital and technological changes to respond to 21st-century requirements, some difficulties still obstruct the transition to new teaching/learning approaches supported by XR technologies. As mentioned earlier, the lack of policies, accreditations and standards could generate an unintegrated and unsustainable development of immersive learning in the construction industry (CITB Research, 2017). Moreover, the uncertainty regarding the scope and purpose of immersive learning associated with the content, investment, benefits, and physical impact (CITB Research, 2017) has generated a fragmented adoption in the construction industry. As a result of these challenges, scholars argued industry organisations and educational providers have struggled to adopt and accept (Venkatesh & Bala, 2008) these technologies in their everyday processes (Rankohi & Waugh, 2013). This research proposes a workflow to translate conventional/traditional learning approaches into immersive learning in response to these challenges. This workflow was obtained through a cross-disciplinary literature review and findings from the Delphi study.

Figure 18 depicts the workflow to design units and learning activities where XR technologies support the learning process. This workflow uses traditional frameworks of teaching design based on learning outcomes (i.e., constructive alignment approach (Biggs, 2014)) complemented with systemic learning models for digital technology (Liu et al., 2020) and acceptance models of technology (Marangunić & Granić, 2015). Few frameworks focus on immersive learning experiences (de Freitas & Neumann, 2009; De Freitas et al., 2010). The framework is based on the idea that the design of teaching/learning activities is highly influenced by the intended learning outcomes (ILOS) defined before the teaching is performed, which at the end describe “what it is intended students should learn, and how they should express their learning” (Biggs, 2014, p. 5). As discussed later, this aspect is critical in the VET sector because it demands assessing the ‘value added’ by any teaching design and renewal to the current conventional training method.

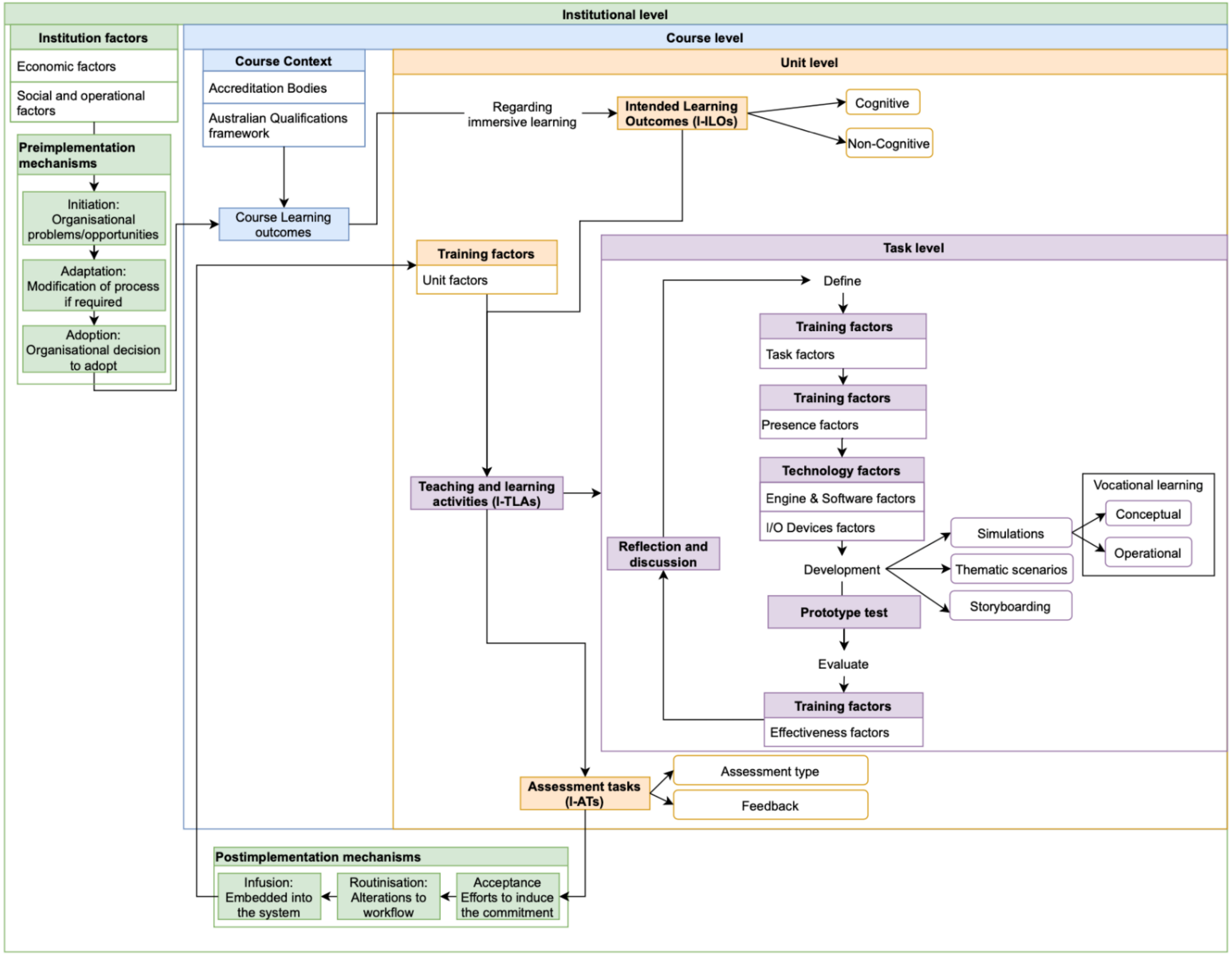

Figure 18. Translating conventional learning into immersive learning.

Before explaining the workflow process and having in mind the constructivist experiential nature of immersive learning, education providers should remember immersive learning experiences are affected by individual attributes. Constructivism means immersive learning is highly influenced by social interactions where students bring prior knowledge to the learning experiences (de Freitas et al., 2010). Indeed, immersive learning uses students' interactions in the virtual context to expose them to real-world scenarios where work-readiness skills and capabilities are acquired and developed (de Freitas & Neumann, 2009). Therefore, this workflow process should be analysed from the perspective that education is experienced in different dimensions beyond the measurable training or qualification.

Biesta (2010) argues education presents three domains: qualification, socialisation, and subjectification. These domains highlight that education could not entirely be controlled because it must consider the active process where students interact and become autonomous of their learning (Barton & Maharg, 2007b; Biesta, 2010). Therefore, although Figure 18 presents a descriptive procedural model to adopt immersive learning considering the 'bounded' context of the VET sector, it is essential to remember immersive learning also demands 'open field' practices (Barton & Maharg, 2007b). The 'open field' practices are not limited to specific learning outcomes; instead, they are associated with unpredictable processes where each student is unique and brings something new through a self-learning process. Indeed, this self-learning factor was included as part of the task factors of the decision-making criteria obtained as part of this research (see section 5.2.1).

In short, this research suggests education providers should involve two types of approaches when designing immersive learning technologies: a 'bounded' and an 'open' field approach (Barton & Maharg, 2007b). In the 'bounded' field approach, learning outcomes are defined to control the adoption process and identify opportunities for improvement. In contrast, in the 'open' field approach, teaching/learning activities should be flexible to address individual and trainees' needs and trainees are encouraged to be more active and autonomous (de Freitas & Neumann, 2009). These two approaches to immersive learning design are also related to the type of simulations developed (De Jong & Van Joolingen, 1998), which will be discussed later.

Independently of the design approach, literature on immersive technology confirmed the adoption process is highly influenced by contextual factors (Ghobadi & Sepasgozar, 2020; Makransky & Petersen, 2021). Thus, this workflow uses the decision-making factors presented in section 5.2 to highlight the importance of considering particular contextual settings that influence the adoption of XR technologies at different levels of VET institutions. In contrast to previous frameworks presented in the literature (de Freitas & Neumann, 2009), the workflow shown in Figure 18 understands the complexity of post-school education and training, including four critical levels (i.e., institutional, course, unit and task levels) in the adoption process. Each level uncovers contextual factors (Sailer et al., 2021) that will influence the integration of immersive technologies.

5.4.1 Contextual factors

The highest level is the institution, which concerns institutional factors related to structure and culture, represented in conditions that will determine how the educational institutions operate. These factors are institutional infrastructure, technical and educational support, standards and commitment, and organisational culture. The institutional infrastructure involves the onsite and online digital infrastructure (Sailer et al., 2021). The technical and educational support is referenced to the support system accessible to the teaching staff and will facilitate their understanding and adjustment in current teaching practices (Sailer et al., 2021). Also, the standards and commitment concern the protocols or regulations available within the institution that could promote or obstruct the short- and long-term adoption of XR technologies in the training processes. This factor is also related to political interest and expectations concerning XR technologies (Liu et al., 2020). Finally, culture integrates the values, attitudes, and identities that determine "the degree of readiness individuals have to act during the adoption process" (Liu et al., 2020, p. 7).

The next level is the course, representing the entire program of studies constituted by units that must be completed to be awarded a qualification. The main factor influencing the adoption of XR technologies at this level is the accreditation bodies, which determine competencies related to specific qualifications that will determine the course learning outcomes. For example, in the case of educational and vocational training in Australia, as discussed in section 1.1.1, the AQF determines the knowledge, skills, and application of knowledge and skills in each VET qualification level (Department of Education Skills and Employment, 2013). These dimensions of VET qualifications are essential to consider because they will affect the scope and considerations of the unit and task learning outcomes defined in the following levels.

The unit level has contextual factors that will determine the suitability of a targeted training mechanism, such as trainees' and trainers' attributes, teaching/learning approach, alignment/sequence with other scheduled teaching activities, and size cohort. First, the trainees' and trainers' attributes refer to factors like age, previous experience and education that depends on the characteristics of trainees and trainers involved in a unit. In addition, the trainees' factors include prior knowledge, profile, presence, motivation, and engagement (Dengel & Magdefrau, 2018; Sailer et al., 2021a), influencing immersive technologies' experience. On the other end, the trainers' factors integrate the attitudes, educational and digital skills that will determine the level of adoption for specific trainers' profiles and, at the same time, will dictate the scope of future training programs available within the institution to prepare trainers for immersive learning approaches. Indeed, previous research has documented that these factors could influence the adoption of XR technologies in the construction industry (Ghobadi & Sepasgozar, 2020).

Second, the teaching/pedagogic approach and alignment/sequence within other scheduled teaching activities emphasise the importance of designing an immersive learning experience considering the suitability with the current training approaches. In this sense, trainers should evaluate if immersive learning initiatives fit with the overall unit teaching/pedagogic approach. Likewise, trainers should analyse how new immersive learning experiences are intertwined in other learning activities to ensure students connect concepts well. Finally, the size cohort of a unit was included as one of the critical considerations because experts in the Delphi study argued there are design and development implications in terms of hardware and software that must be examined for different sizes of cohorts.

The last contextual factors are related to the task, determining the characteristics and features of learning activities. One essential factor at this level is the task goal, as suggested in the qualitative ranking in Round 1 of the Delphi study. Training task goals refer to the learning objectives associated with specific knowledge, skills, and attitudes. This factor will affect the rest of the task-related factors, such as the task type or instructions. The importance of this factor is consistent with the approach adopted in the workflow process based on the constructive alignment of learning activities (Biggs, 2014), which gives special attention to the intended learning outcomes. The following sections will discuss the workflow process in detail.

5.4.2 Designing immersive learning experiences

The proposed workflow process has four stages: defining intended learning outcomes, designing teaching and learning activities, designing assessment tasks and a crucial stage that should be done before and after each implementation at the institutional level to ensure the acceptance of immersive learning strategies in a long-term basis. As observed in Figure 18, the first three stages have an 'I', which indicates the process exclusively refers to the immersive learning scope that could complement, or should be complemented by, the conventional training processes.

Immersive intended learning outcomes (I-ILOs)

The first stage refers to the definition of intended learning outcomes related to immersive learning (I-ILOs), which could be at the unit or task level. In the case of unit level, these I-ILOs are restricted by conditions and requirements presented by accreditation bodies. Therefore, educational providers should consider the AQF framework in the Australian vocational training context or any reform made to this framework. It describes the skills and knowledge required for each qualification level. These requirements will provide the purpose of the teaching and learning activities in addition to limitations.

Educational providers and trainers should be aware that I-ILOs should involve both cognitive and non-cognitive learning outcomes at the unit or task level. This mix of learning outcomes is essential in the VET sector to introduce students to technical and socioemotional skills demanded in the workforce. On the one hand, cognitive I-ILOs refer to basic digital skills and professional knowledge and skills, which are easier to control and measure. It is recommended to use the SOLO Taxonomy presented by Biggs (2003) to design these ILOs, dividing learning objectives into five levels (Figure 19). Examples of these cognitive I-ILOs could involve conceptualising building components (Glick et al., 2012), comprehending hazard recognition in construction sites (Lin et al., 2011), identifying construction materials and methods (Park et al., 2016), among others.

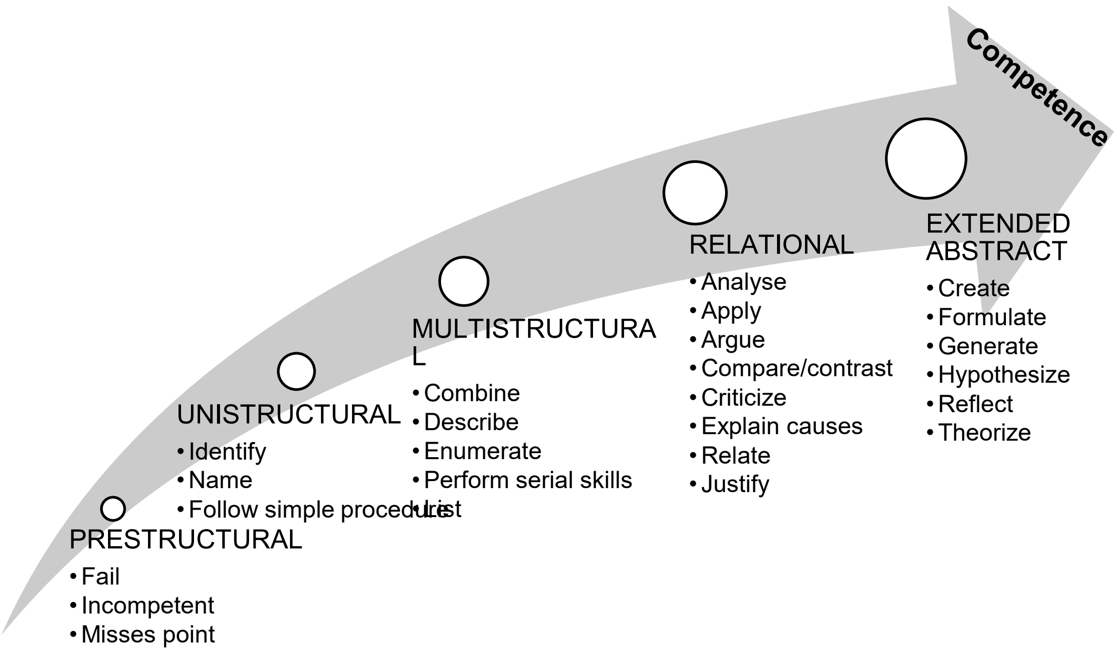

Figure 19. SOLO Taxonomy for learning outcomes (adopted from (Biggs, 2003))

Besides cognitive outcomes, trainers should consider non-cognitive learning outcomes associated with 'soft skills'. While these learning outcomes have not been intensely studied in the literature of immersive learning, some studies (Makransky & Petersen, 2021, p. 951) have developed learning models recently to describe how immersive learning experience could facilitate "interest, intrinsic motivation, self-efficacy, and embodiment" that consequently will trigger soft competencies such as teamwork, communication, critical thinking, creativity, etc. Therefore, trainers must focus on these types of variables required to develop social-affective skills demanded in the workforce.

Immersive teaching and learning activities (I-TLAs)

Once the learning outcomes related to immersive learning or XR technologies are defined, the teaching and learning activities design is started. As observed in Figure 18, the first step involves the definition of task factors which will determine the characteristics and features of learning activities. For example, trainers must define the type of activity students perform depending on how they use technology and how they are cognitively stimulated and engaged with it (Sailer et al., 2021). Thus, tasks could be categorised into passive, active, constructive, and interactive activities. Moreover, task attributes such as self-learning, repeatability, instructions, enjoyment, and engagement will conditionate the presence factors which constitute the following step.

As defined in the decision-making criteria, presence factors influence the feeling and trainees' perception of being. Scholars argue this factor highly affects the learning outcomes in immersive learning activities (Dengel & Mägdefrau, 2019). Presence factors "contain(s) the subjective elements of physical, social, and self-presence, referring to different domains of human experience" (Dengel & Mägdefrau, 2019, p. 186). However, Dengel and Mägdefrau (2019) indicated there is no common agreement in measuring the presence of virtual enrolments because the literature has been assessing it using subjective variables in post-experiment questionnaires. As a result, Dengel and Mägdefrau (2019) propose a model of objective technological variables where the characteristics of the immersive material or virtual environment will drive the trainee's feeling of being present. Hence, in the workflow process, the presence definition implicates determining the immersion, realism degree and type of interactions (Pantelidis, 2009). During this step, it is critical to evaluate how these variables could induce simulator sickness, which has been documented as one of the factors that could obstruct students' performance in the immersive learning activity (Dengel & Mägdefrau, 2019).

The following step concerns the development of applications and the definition of technology considerations. Although some features are fixed according to each I/O device, such as weight, motion constraints, power, battery, etc., this step aims to select the most appropriate device that satisfies the task features set in the previous step based on the technology factors (see the decision-making criteria in Figure 17). Additionally, this step involves the development of simulations, thematic scenarios, and storyboarding. One of the key issues that differentiates immersive learning from any other educational approach is the use of simulations that could be developed in particular teaching/learning activities.

The simulations compose an extrapolation of reality required in an educational task (Barton & Maharg, 2007a). Therefore, when simulations are used, educational providers and designers should consider three intertwined main aspects: "educational intention and design (why), disciplinary content (what), and simulation reality (how)" (Barton & Maharg, 2007a, p. 117). Based on this, educational providers must acknowledge there are two types of simulations depending on the models contained and the learning outcomes to be promoted.

There are simulations with conceptual or operational models (De Jong & Van Joolingen, 1998). De Jong and Van Joolingen (1998, p. 180) clarify these terms: “Conceptual models hold principles, concepts, and facts related to the (class of) system(s) being simulated. Operational models include sequences of cognitive and noncognitive operations (procedures) that can be applied to the (class of) simulated system(s)”. The design of simulations relies on the task goal, scope and purpose, which delimit the trainees’ role and participation.

Trainees in immersive learning are more active and autonomous (Pantelidis, 2009). Therefore, one key aspect to consider when developing the storyboarding is the ‘narrative’, which should be ‘motivational’ (de Freitas & Neumann, 2009, p. 345). This means the ‘narrative’ should support the interactions defined in the presence factors. This consideration is decisive to enhance the learning process through active integration of interactions (Barton & Maharg, 2007).

The following stage involves two steps: prototype testing and effectiveness evaluation. Pantelidis (2009) suggested prototype testing using a pilot group of trainees could be beneficial to evaluate the simulation and modify it. This step should be targeted to analyse how effective the learning experience compares with the expectations of the trainees and trainers. One of the most important frameworks for this evaluation is the Technology Acceptance Model (TAM) (Venkatesh & Bala, 2008). This model investigates the factors that influence the users’ acceptance of technology (Marangunić & Granić, 2015). This is highly important because aspects such as perceived usefulness or ease of use/adoption on behalf of trainers could obstruct the XR technology adoption in the VET sector (Marangunić & Granić, 2015).

Additionally, the effectiveness factors should be evaluated in conjunction with concepts of ‘transfer’ (de Freitas & Neumann, 2009). To quote de Freitas & Neumann (2009, p. 348): “The stage of reflection is crucial for facilitating the higher-order cognition and aiding transfer between virtual and lived experiences. Therefore, the role of meta-reflection in learning with e-learning tools is central to the effectiveness of learning.” The reflection is the ideal space where trainers could receive feedback and trainees could be introduced to discussions and debates to strengthen the concepts, knowledge or skills promoted. Indeed, from the effectiveness evaluation and the reflection process, the teaching/learning activities are constantly reviewed to be aligned with trainers’ and trainees’ needs. The following stage in the workflow process is the design of assessment tools, which is undertaken once the teaching/learning task is completed.

Immersive assessment task (I-Ats)

The assessment tasks aim to evaluate and analyse the trainees’ performance. As discussed in the Delphi study, although assessment tasks are not always recommended in the VET sector because there are still trainees unwilling to participate in immersive learning experiences, de Freitas & Neumann (2009) argue immersive learning always requires validating the learning. However, immersive learning cannot be promoted as effectively using conventional assessment tools like tests or exams. Thus, de Freitas & Neumann (2009) propose ‘lifelong learning’ mechanisms where students could critique and evaluate themselves. ‘Lifelong learning’ strategies are helpful when trainees do not perceive the usefulness of particular learning. This is critical in the VET sector because the profile of the students is not commonly interested in technology application; therefore, as a solution, trainers could involve trainees in the assessment process. What is important to highlight in this stage is that although it is not always possible to develop formal assessment, trainers should always promote a reflective process where trainees can internalise the tasks, knowledge and skills.

Acceptance at the institutional level

As part of this workflow process, the last consideration is the actions that will ensure the long-term transformation and adoption of immersive learning. From TAM, Venkatesh & Bala (2008) emphasise the importance of promoting pre- and post-implementation interventions that will facilitate the implementation and ensure the acceptance of teaching/learning renewals towards immersive learning at the institutional level. Table 6 summarises the pre- and post-implementation interventions with their correspondent objective. Likewise, this research proposes considerations for each stage to highlight the importance of involving trainers throughout the process. This means that trainers' needs and requirements are critical for successfully implementing XR technologies as part of training programs. This aspect was stressed during the focus groups with the teaching staff. They noted that to adopt XR technologies, they must feel confident using the technologies and aware of the benefits these technologies will bring to the current training practices.

Table 6. Pre- and post-implementation interventions to ensure long-term acceptance of immersive learning experiences (Adapted from Venkatesh & Bala (2008).

Stage	Interventions	Objective	Considerations
Pre-implementation	Initiation	"Identification of organizational problems/opportunities that warrant a technology solution"	• Understand trainers' requirements, interests, and needs. • Develop strategies where trainers are actively involved. • Strengthen the technical and educational support for trainers. • Develop standards related to a continuous improvement process to consider trainers' feedback. • Communicate renewal benefits to trainers. • Avoid overload to trainers' responsibilities.
	Adoption	"Organisational decision to adopt and install a technology"	
	Adaptation	"Modification processes directed toward individual/organisational needs to better fit the technology with the work setting"	
Post-implementation	Acceptance	"Efforts undertaken to induce organisational members to commit to the use of technology"	• Support trainers in the transformation process where they can perceive how

Stage	Interventions	Objective	Considerations
	Routinisation	“Alterations that occur within work systems to account for technology such that these systems are no longer perceived as new or out-of-the ordinary”	those changes could enhance their job performance. • Restructure training programs to ensure trainers confront and improve perceived usefulness and ease of adoption. • Consider improvement to the system support. • Develop programs of peer support between trainers.
	Diffusion	“Technology becomes more deeply embedded within the organization’s work system”	

On the other hand, the interventions to ensure long-term acceptance of technology training changes at the institutional level emphasise the critical role of trainers during the adoption process. As discussed earlier, the technical and educational support should focus on strategies that will facilitate the adoption process at the unit level dealing with particular trainers’ features. However, although this support system looks complex, literature has advocated that certain trainers’ skills could ease the use and adoption of XR technologies. Indeed, these trainers’ skills could be improved using training programs to ensure trainers increase their perception regarding usefulness and ease of adoption of XR applications.

5.5 Trainers’ skills and training implications

Trainers require three aspects to implement immersive learning: basic digital skills, technology-related teaching skills, and beliefs/attitudes (Sailer et al., 2021) (see Table 7). Before describing each of these skills, it is important to consider three points. First, trainers in vocational training require targeted knowledge and skills to ensure the correct transmission of content and the development of students’ competencies. In the VET sector, teaching demands practical and experiential expertise in addition to theoretical and practical knowledge. Second, considering that technology is constantly changing and evolving, trainers require adaptative skills to be open to new technologies and an understanding of specific software and hardware (Mishra & Koehler, 2006). Third, all aspects of trainers’ skills must be considered in trainers’ professional development (Mishra & Koehler, 2006), implying that technology and pedagogy-related knowledge would be regarded as when trainers are prepared for immersive technology implementations. In these cases, it is suggested to provide real examples of how to use immersive learning in vocational training with considerations and recommendations; even the use of peer mentors could be beneficial (Stieler-Hunt & Jones, 2019).

Table 7. Trainers' skills and implications.

Attribute(s)			Description
Basic digital skills			Standard technological skills are required to interact and live in 21st-century digital conditions (i.e., internet, email, digital resources, and sources).
Technology-related teaching skills	Content knowledge (Mishra & Koehler, 2006) and skills	Technical knowledge	Related to “concepts, theories, ideas, organisational frameworks, knowledge of evidence and proof, as well as established practices and approaches toward developing such knowledge” (Mishra & Koehler, 2009, p. 63).
		Practical and professional knowledge	It exceeds the practical technical knowledge considering the importance of professional and industry-related expertise.
	Pedagogy knowledge(Mishra & Koehler, 2006) and skills		It is related to education variables that interfere in how the content knowledge is transmitted and delivered to students.
	Technology knowledge (Mishra & Koehler, 2006) and skills		It is related to knowledge of technologies relevant to a particular field. Additionally, it includes the skills “to operate particular technologies,”, hardware and software (Mishra & Koehler, 2006, p. 1027).
Beliefs/attitudes			It is related to the level of trainers’ openness to technological change in educational spaces.

5.5.1 Basic digital skills

Basic digital skills concern standard technological skills required to operate general hardware and interact in 21st-century digital conditions (i.e., internet, email, digital resources, and sources). Sailer et al. (2021) suggest trainers even require the same set of skills that are demanded in students. Basic digital skills constituted a prerequisite to use XR technologies; however, they “are not sufficient for a teacher’s ability to provide the full scope of learning opportunities to students” (Sailer et al., 2021, p. 7).

5.5.2 Technology-related teaching skills

The Technoligical Pedagogical Content Knowledge framework (Mishra & Koehler, 2006) presents a framework for teaching knowledge when technology is used. It was decided to use this framework as a foundation because it is the most cited framework regarding training consideration. This framework suggests trainers require three kinds of knowledge: content, pedagogical and technological. Nevertheless, as was previously discussed, trainers need both knowledge and skills to ensure the correct transmission of the practical and industrial approach in vocational training. Therefore, content-related knowledge should be understood as technical and practical/ professional knowledge in a particular field required to achieve the learning outcomes.

Pedagogy-related knowledge involves understanding educational strategies that should be adapted to a particular unit context to get certain educational aims and purposes (Mishra & Koehler, 2006). However, the unit is not an isolated context; somewhat, it is affected by institutional and course factors. Thus, pedagogy knowledge must involve a basic understanding of curriculum design and evaluation/control to suggest unit renewal and new configuration based on student performance and engagement.

Technology-related knowledge refers to technology understanding and operation of hardware and software used in a specific field. For example, if trainers do not know how to select and implement immersive technology according to teaching and learning requirements, they will not be motivated to use them (Stieler-Hunt & Jones, 2019).

Technology-related teaching skills are interconnected through complex relationships (Mishra & Koehler, 2009). Technology-related knowledge completely changes the content and pedagogical-related knowledge because trainers now require analysing how the content is more accessible through technological implementation and how the technology responds to pedagogical concerns. For instance, technology facilitates the communication of different design systems in a building in the construction industry. Therefore, trainers should adapt the content to a higher cognitive level where students understand the complex relationships between systems that could generate design clashes. In this way, trainers could use the technology to enhance the work-readiness of students' competencies. Mishra and Koehler (2006) suggest that when trainers desire to use technology-based strategies, they must wisely decide the best knowledge set (including content, pedagogy, and technology) required in a particular unit or task because not all technology solutions respond to all students' demands.

5.2.3 Trainers' beliefs and attitudes

Trainers' beliefs and attitudes concern the enthusiasm to implement immersive learning as an educational approach. It is believed trainers with high content and technology-related knowledge have more positive attitudes towards technology implementation in education (Sailer et al., 2021). The lack of adoption could be a consequence of trainers' ignorance regarding the educational benefits of XR technologies (CITB Research, 2017); indeed, trainers could feel frustration and resistance when they do not know the correct strategies to use them. However, the reflective exercises between trainers and technology experts about their use of technology could enhance the technological-related skills and consequently trigger trainers' positive attitudes.

These sections have described the trainers' implications regarding the skills and attitudes required to adopt XR technologies in the VET sector successfully. In addition, this research highlighted the general challenges and considerations that VET providers must evaluate before starting the development process of XR applications (see section 5.1). Importantly, VET providers should define the justification of adopting XR technologies based on their current training to guarantee that XR applications respond to specific trainees' and trainers' requirements. Likewise, mitigation strategies must be created by VET providers to reduce the influence of considerations such as technology evolution, fragmented industry or lack of government support. For instance, some champions of VET providers could inspire the adoption by showcasing examples of successful use.

Aligned with the previous points, the most important outcomes of this research were the decision-making criteria and the workflow process. These tools will facilitate the adoption process of XR technologies. The decision-making criteria obtained from the literature review and evaluated with the Delphi study, together with the workflow process, will enhance the selection process of XR technologies to ensure all factors are considered from the beginning. However, it is essential to note that these tools need to be validated in real-life scenarios as suggested in the following section.

6. CONCLUSIONS, RECOMMENDATIONS AND FUTURE RESEARCH ON XR TECHNOLOGIES IN THE VET SECTOR

The conclusions are listed for each research objective as part of this scoping study:

Obj 1: To evaluate the significant challenges and identify the opportunities for the use of innovative virtual reality/augmented technologies in existing vocational training.

The Australian construction industry has been experiencing an ongoing skills shortage because professionals do not have the required job-related skills that the industry demands in new large-scale projects and 21st-century conditions. This research explained how technological changes boosted by the fourth industrial revolution have changed the skillsets required in the construction workforce. However, due to this labour shortage, construction companies have experienced problems in the recruitment process, increasing operating costs and workloads for other workers in construction projects. The VET sector needs to update its teaching delivery process addressing the demands of the labour market and new technological conditions to enhance the skill sets and employability status of all working-age Australians and consequently contribute to Australia's economy and productivity. Here immersive learning arises as an excellent cost-effective teaching/learning approach in response to the new digital and job-ready skills demanded in construction trades.

Obj2: To identify the available digital technologies (VR/AR/MR) for different types of VET skill development in the AEC industry.

Although the number of cases studying the transformation of educational training using immersive learning has been increasing in the literature, little is known about considerations and recommendations to ensure the holistic integration of XR technologies in construction vocational training. Therefore, different case studies were analysed to determine special considerations, advantages, and limitations of the most common XR technologies used in construction training (i.e., Non-immersive VR (Desktop-based VR), immersive VR, Game-based VR, BIM-enabled reality technology, Augmented reality (AR) technology, Mixed reality (MR)). Although there is no consensus between academics on the most appropriate technology to be used in construction training, the critical point suggested as part of this research is to analyse how each technology responds to the specific training requirements.

Obj3: To develop an appropriate workflow process for translating conventional vocational skill training in a virtual reality/augmented reality environment.

Based on an in-depth literature review, the most important criteria influencing the adoption of XR technologies in education was determined. Likewise, these criteria were enriched with VET experts' opinions following a Delphi study approach obtaining additional information to propose a workflow process to translate the current and conventional training approach into an XR-based training approach.

Obj4: To recommend how to adapt effectively digital technologies (VR/AR) in vocational skill training for the building industry.

In summary, as part of the recommendations of this research, the VET sector needs to justify the adoption of XR technologies by defining the XR application goals, strategies of control and trainees' needs. Further, before undertaking any storyboard development, this assessment process should be done to ensure the technology supports the learning outcomes and is integrated into the overall course. These aspects are elemental to evaluate because XR technologies evolve rapidly, and hardware may become outdated soon. Similarly, educational providers should involve trainers in the transition to assure their requirements, interests, and needs are addressed. Likewise, it is essential to create a technical and educational support system for trainers where they can become confident using the XR application, harness the benefits of immersive learning and perceive how XR technologies could enhance their job and training performance.

Finally, further research is required to test the decision-making criteria and the workflow process considering the complex structure of the VET sector. It would be crucial to test the practicality and effectiveness of XR technologies such as VR, AR and MR technologies for different certifications and trade short courses under vocational education and training programs. It is essential to conduct higher-order experimental studies based on the decision-making criteria and workflow process to find the proper XR technology for selected VET programs in the field of building construction. As argued in this research, previous work focused on immersive learning failed to determine the adoption considerations for developing specific skill sets. Therefore, further research should involve prototypes for each qualification level to determine trainers' and trainees' needs and technology requirements. This process will give insight into the suitability of the different types of XR technologies in particular VET contexts.

At the same time, future studies are recommended to measure the costs of implementing the XR technologies in the VET system as part of digital transformation for training a high-skilled workforce for the future building industry. In addition, the industry, academia, and government might work together to support the broader adoption of immersive learning to tackle challenges documented as part of this project. These new digital technologies could help integrate better physical activities with a virtual construction environment to promote hybrid training at the construction site. The researchers and industry practitioners believe the XR technology has a definite future to encapsulate the essential training needs for supporting resilient human resources development in design and building construction.

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APPENDIX I. TYPES OF IMMERSIVE LEARNING IN CONSTRUCTION

Table I-1. XR technologies used in construction.

Type of XR technologies	Purpose	Hardware	Special considerations	Outcomes	Advantages	Limitations	Examples
Non-immersive VR (Desktop-based VR)	To provide virtual tasks in a 3D virtual environment.	Desktop screen, keyboards and mouse (P. Wang et al., 2018).	It requires students' spatial and perception abilities (P. Wang et al., 2018).	Enhances students' understanding of complex spatial arrangements (Glick et al., 2012; Vergara et al., 2017).	Economical alternative. Generates lower education costs.	Does not provide full sense of immersion (Rezazadeh et al., 2011).	(Fogarty et al., 2018).

Type of XR technologies	Purpose	Hardware	Special considerations	Outcomes	Advantages	Limitations	Examples
Immersive VR	To simulate students' physical presence in an immersive environment through producing realistic sounds, images, and other emotions	Specific hardware such as sensor gloves and the head-mounted device (HMD) (P. Wang et al., 2018). Could be supported by control devices particularly tracking tools for interactions, including motion tracking devices and game controllers.	It must be supported with sounds, images, and other virtual scenarios with the aim to simulate a real "virtual" environment.	Enhances students' motivation, creativity and understanding of complex designs (Alizadehsalehi et al., 2019b). Students are more concentrated.	Excellent alternative for visualise complex design problems. Could be adapted to provide real-time feedback (Burns & Ausburn, 2007).	Requires high development data and interoperability between software.	(Sacks & Pikas, 2013).

Type of XR technologies	Purpose	Hardware	Special considerations	Outcomes	Advantages	Limitations	Examples
Game-based VR	To enable 3D real-time interaction in virtual environments (Sampaio et al., 2013). To magnify students' interactions using the combination of network, interactive, visual, and multi-user operating technologies.	Includes game controllers, mouses, and keyboards to do virtual activities.	Focuses more on the interactions of game objects. Therefore, objects should be developed by both their collision boundaries and geometric properties.	Facilitates the prototypes testing using 3D content creation.	Excellent alternative to be used as an assessment method (H. Li et al., 2012b) and "risk-free" environment for safety training (H. Li et al., 2012a). Enhances the interaction and collaboration among trainees (H. Li et al., 2012b).	Demands high development time (H. Li et al., 2012a).	(H. Li et al., 2012b)

Type of XR technologies	Purpose	Hardware	Special considerations	Outcomes	Advantages	Limitations	Examples
BIM-enabled reality technology	To incorporate 3D objectives' properties information required through the entire life cycle of construction projects (Gheisari & Irizarry, 2016).	Varies according to the expected use, but it can uses phones, tablets, among other devices (Wang et al., 2014).	Relies on models, highlighting the connections and data binding behind other VR systems, to simulate construction and operations processes.	Promotes the practical experience in virtual context.	Facilitates the architectural visualisation and accessibility of data (e.g., material type and cost) in construction projects (Wang et al., 2014). As a result, it simplifies the decision-making and communication between stakeholders (Wang et al., 2014).	Could be limited to compatibility problem that obstruct the transmission of real-time information (Xie et al., 2011).	(Wang et al., 2014)
Augmented reality (AR) technology	To provide live direct or indirect prospects of a physical context with augmented virtual information.	Mostly, the computer-generated content can only be viewed from tablet and smartphone devices.	The sensory technologies can provide graphics, videos, and sounds. There are four kinds of AR: 1) maker-based AR, 2) location-based AR, 3) projection-based AR, and 4) superimposition-based AR (Alizadehsalehi et al., 2020).	Enhances students' engagement and motivation due to it is supported by active learning (Ayer et al., 2016).	There are more applications available to be set up in mobile devices. Excellent alternative to monitor processes and identify defective works.	There is no interaction between the real-world and computer-generated contents. Some AR devices represent very restricted immersive viewing experiences.	(Ayer et al., 2016)

Type of XR technologies	Purpose	Hardware	Special considerations	Outcomes	Advantages	Limitations	Examples
Mixed Reality (MR)	To allow the digital content to be interactive with the real world (Wang & Dunston, 2008).	Mixed Reality headsets.	Some students could experience physical discomfort (Wang & Dunston, 2008).	Enhances the comprehension of design systems reducing mistakes in construction (Chalhoub & Ayer, 2018).	Useful when it is required overlapping/interaction between the physical and virtual environment on construction sites (Chalhoub & Ayer, 2018). Moreover, it is convenient users do not have assembly experience (Chalhoub & Ayer, 2018). Promotes creativity and problem-solving skills and users' satisfaction (Wang & Dunston, 2008).	Rapid advancement of technology obstructs the adoption in the construction industry.	(Wang & Dunston, 2008)

APPENDIX II. MARKET SURVEY RESULTS

Table II-1. Australian XR Capable Development Companies.

PROVIDER NAME	URL	LOCATION	STATE	XR TYPE	XR DEVICES	DEV. PLATFORM	TRAINING TYPE
2EXCEL	https://www.2excel.com.au/	Adelaide	SA		Mobile Devices	Web, iOS, Android	
3D WALKABOUT	https://3dwalkabout.com.au/	Perth	WA	VR, AR	HMD (HTC, Oculus), Hand-held Device	Unity	Mining operation workforce training, OHSA safety training, Healthcare training, Retail staff training, Hospitality training
7DX	https://7dx.co/	Sydney	NSW				Multiple staff training, specific industry-related training
7YM	https://7-ym.com.au/	Melbourne	VIC				
ACHIEVR	http://www.achievr.zone/	Sydney	NSW	VR, AR	HMD (HTC, Oculus), Hand-held Device	Unity	Crane operator training, Operational efficiency in food manufacturing, Fire fighting training, Fast food fryer safety, Signalman training

PROVIDER NAME	URL	LOCATION	STATE	XR TYPE	XR DEVICES	DEV. PLATFORM	TRAINING TYPE
ACTIVATE STUDIOS	https://activatestudios.com/	Brisbane	QLD	VR, AR	HMD, Hand-held Device	Unity, Web, iOS, Android	-
APPEARITION	https://www.appearition.com/	Melbourne	VIC	VR	HMD, Hand-held Device	Unity, Web, iOS, Android,	Education training, customer-specific training
APPELLO SOFTWARE	https://appello.com.au/		NSW, VIC, SA, WA, ACT, QLD		Hand-held Device	Web, iOS, Android	
ARE		Melbourne	VIC				
AUGMENTED REALITY EXPERTS	https://www.augmentedrealityexperts.com.au/applications/	Melbourne	VIC	VR, AR	HMD, Hand-held Device	Unity, Web, iOS, Android	Workplace training
AURECON (AKA UNSIGNED STUDIO?)	https://www.aurecongroup.com/expertise/digital-engineering-and-advisory/case-studies/christchurch-bus-interchange	Christchurch (NZ), Perth	WA	VR	HMD (Oculus)	Unity, Unreal (?)	Safety awareness training
AUSTECHVR	https://austechconnect.com.au/	Gold Coast	QLD	VR	HMD	Unity	-

PROVIDER NAME	URL	LOCATION	STATE	XR TYPE	XR DEVICES	DEV. PLATFORM	TRAINING TYPE
AVEVA GROUP	https://www.aveva.com/en/solutions/digital-transformation/xr/	[International] Cambridge UK					
BONDI LABS	https://www.bondilabs.com/	Melbourne	VIC	VR	HMD	Unity, Unreal Engine	Customs Quarantine training, Healthcare, engineering, oil and gas technical training
CATALYST VR	https://catalystvr.com.au/	Sydney	NSW	VR, AR	HMD (HTC, Oculus), Hand-held Device	Unity, Web, iOS, Android	NSW SES Training
CHAMPAGNE SODA	No URL						
CHAOS THEORY	https://www.chaostheorygames.com/australian-serious-game-developer	Sydney	NSW	VR, AR	HMD (HTC, Oculus), Hand-held Device	Unity, Web, iOS, Android	Advertising, Entertainment, Medical, Aviation, Health and Safety, Other Training
DELOITTE (FORMER WELL PLACED CACTUS, KID		Brisbane, Melbourne, Sydney	QLD, VIC, NSW	VR, AR			

PROVIDER NAME	URL	LOCATION	STATE	XR TYPE	XR DEVICES	DEV. PLATFORM	TRAINING TYPE
NEON VR STUDIOS)							
EMERGEWORLDS	https://emergeworlds.com/vr-training	Brisbane	QLD	VR	HMD	Unity, Web, iOS, Android	Ambulance and First Aid training
EON REALITY	https://eonreality.com/platform/						
EXNER EDUCATION	https://www.exner.com.au/	Melbourne	VIC	VR	HMD (HTC, Oculus)	Unity	Mining, Engineering, Construction Industry Training
FACILITATE	https://www.facilitate.tech/	?	?	VR, AR	HMD (HTC, Oculus)		virtual training environment, customer-specific training
FGMNT	https://www.fgmnt.tech/		VIC				
FIRST AID VR	https://firstaidvr.com.au/						
FOLOGRAM	https://fologram.com/	Melbourne	VIC	AR	Hololens 1&2 iOS, Android		Plugin for design software; Rhino & Grasshopper

PROVIDER NAME	URL	LOCATION	STATE	XR TYPE	XR DEVICES	DEV. PLATFORM	TRAINING TYPE
GHD (IN HOUSE TEAM D-LAB)	https://www.ghd.com/en/projects/virtual-incident-response-and-command-training-solution.aspx https://www.ghd.com/en-au/expertise/digital.aspx		QLD, VIC	VR, AR	HMD	Unity, Unreal Engine, Web, iOS, Android	In-house simulations, client-based custom training and simulation
GLARE DIGITAL	https://digitalglare.com.au/						
HYDRIC MEDIA	http://www.hydricmedia.com/						
IDYA TECHNOLOGY	https://www.idya.com.au/augmented-reality/						
IGNITION IMMERSIVE	https://immersive.video/	Melbourne					
IMMERSE ENTERPRISE	https://immerseenterprise.com/	CLOSED, Brisbane, Sydney, Melbourne,		VR	HMD	Unity	Forklift VR Training, Sewerage Treatment Site Training, Mining Training Scenarios

PROVIDER NAME	URL	LOCATION	STATE	XR TYPE	XR DEVICES	DEV. PLATFORM	TRAINING TYPE
		Darwin, ACT					
IMMERSEPORT	http://www.immerseport.com/						
IMMERSIFAI							
IMMERSIVE TECHNOLOGIES	https://www.immersivetechnologies.com/index.htm				HMD		Mining equipment and vehicle operator training simulation
INFINITY AMUSEMENTS	https://www.infinitycapture.com/		VIC				
ISONOMIC	https://www.isonomic.org/	Sydney	NSW				Mining, Engineering, Construction Industry Training
LAING O'ROURKE		(UK)		VR		Unity	
LAST PIXEL	https://lastpixel.com.au/	Perth	WA				

PROVIDER NAME	URL	LOCATION	STATE	XR TYPE	XR DEVICES	DEV. PLATFORM	TRAINING TYPE
LENS IMMERSIVE	https://lens-immersive.com/						
LIGHTWEAVE	https://lightweave.co/	Brisbane	QLD		HMD, Hand-held Device	Unity, Web, iOS, Android	-
LIMINALVR	https://liminalvr.com/training-simulation/	Melbourne	VIC	VR	HMD	Unity	Fire safety training, Industry training, Agriculture skill training, and more...
MAXART	https://www.maxart.com.au/case-studies	Brisbane	QLD	VR, AR	HMD, Hand-held Devices	Unity, Unreal Engine	Vehicle driving simulation, mechanic training, sports ethics training, healthcare training
MINESTAR SOLUTIONS	https://www.cat.com/en_US/by-industry/mining/minestar-solutions.html						
NESTED REALITIES	https://www.nestedrealities.com.au/						
NEW WORLD ENTERPRISES	https://nextworldenterprises.com/	Brisbane	QLD	VR	HMD (Oculus, Pico Neo 3)	Unity	Safety training

PROVIDER NAME	URL	LOCATION	STATE	XR TYPE	XR DEVICES	DEV. PLATFORM	TRAINING TYPE
OCEANIC STUDIOS	https://www.oceanicstudios.com/	Melbourne	VIC				
PANEDIA	https://www.panedia.com/	Sydney	NSW				
PHORIA	https://www.phoria.com.au/	Melbourne	VIC				
PIXELCASE GROUP		Perth	WA				
PLATTAR	https://www.plattar.com/	Melbourne	VIC		Hand-held Device	Web, iOS, Android	
POINTSBUILD							
QUITESENSIBLE	https://quitesensible.com/	Gold Coast	QLD	VR	HMD	Unity, Web, iOS, Android	-
RAYTRACER	https://raytracer.co/	Brisbane	QLD	VR	HMD	Unreal Engine	Astronaut simulation training, Military applications

PROVIDER NAME	URL	LOCATION	STATE	XR TYPE	XR DEVICES	DEV. PLATFORM	TRAINING TYPE
REAL SERIOUS GAMES	https://realseriousgames.com/	Brisbane	QLD	VR	HMD (Oculus)	Unity	Mining, Engineering, Construction Industry Training
RED CARTEL							
RYAN AEROSPACE	https://www.ryanaerospace.com.au/	Gold Coast	QLD	VR	HMD (Varo, HTC, Oculus)	User chooses platform. Hardware designed for flight simulations	
SNOBAL	https://snobal.io/		VIC		HMD, Hand-held Device	Unity, Unreal (?), Web, iOS, Android	design collaboration, industry training
STAPLES	https://www.staplesvr.com/	Melbourne, Sydney	VIC, NSW	VR	HMD (HTC)	Unity, Web, iOS, Android	Aircraft maintenance training, Truck driver training, healthcare simulation, civil engineering staff onboarding
TWINBUILD	https://twinbuild.com/	Melbourne	VIC	AR	MS Hololens 1&2		Construction site activities & progress monitoring

PROVIDER NAME	URL	LOCATION	STATE	XR TYPE	XR DEVICES	DEV. PLATFORM	TRAINING TYPE
TAFE QLD (SOLDAMATIC)		Brisbane	QLD	VR, AR	Custom-built welding simulator		
THOROUGHTEC SIMULATION	https://www.thoroughtec.com/	Perth	WA	VR	CAVE systems,		
TRIGGAR		Sydney	NSW				
ULTRAREM							
VALIS XR	https://www.valis.com.au/		VIC				
VANTARI VR							
VIRTUAL DREAM	https://virtualdream.com.au/vr-training/	Brisbane	QLD	VR			
VISUAL PLAYGROUND							
VITAMIN T	No URL		VIC				
VRCREATIVESOLUTIONS		Adelaide	SA				

PROVIDER NAME	URL	LOCATION	STATE	XR TYPE	XR DEVICES	DEV. PLATFORM	TRAINING TYPE
VRNOW		Brisbane	QLD				
VUYU							
WORLDVIEW							
XRJV	https://www.xrjv-training.com/						
ZEALAR			VIC				

APPENDIX III. OVERALL FINDINGS FROM THE DELPHI STUDY

Table III-1. Analysis 1 Summary - Participant perception of the importance of each factor is related to their Roles

Factor	*p-value*	*Statistically Significantly Different ($p < 0.05$)*	*Groups with significantly different opinions*
[**Size of cohort**]	0.2727	No	-
[**Learners' and trainers' attributes**]	0.3421	No	-
[**Maintenance**]	0.2571	No	-
[**Customisation degree**]	0.4248	No	-
[**Simulator sickness**]	0.1147	No	-
[**Power and battery**]	0.9796	No	-
[**Training task goals**]	0.9655	No	-
[**Interoperability**]	0.0602	No	-
[**Flexibility**]	0.6673	No	-
[**Realism/fidelity**]	0.7451	No	-
[**Self-learning**]	0.3021	No	-
[**Institutional infrastructure**]	0.0200	Yes	Leadership and Teaching/Tech Staff

Table III-2. Analysis 2 Summary - Participant perception of the importance of each factor is related to their XR Familiarity

Factor	*p-value*	*Statistically Significantly Different (p < 0.05)*	*Groups with significantly different opinions*
[**Size of cohort**]	0.6496	No	-
[**Learners' and trainers' attributes**]	0.6226	No	-
[**Maintenance**]	0.0982	No	-
[**Customisation degree**]	0.6236	No	-
[**Simulator sickness**]	0.0026	Yes	2 - Slightly and 3 – Moderately 2- Slightly and 4 - Very
[**Power and battery**]	0.9682	No	-
[**Training task goals**]	0.2989	No	-
[**Interoperability**]	0.0869	No	-
[**Flexibility**]	0.7745	No	-
[**Realism/fidelity**]	0.3278	No	-
[**Self-learning**]	0.0505	No	-
[**Institutional infrastructure**]	0.8814	No	-

Table III-3. Analysis 3 Summary - Participant perception of the importance of each factor is related to their Training and Teaching Familiarity

Factor	*p-value*	*Statistically Significantly Different (p < 0.05)*	*Groups with significantly different opinions*
[**Size of cohort**]	0.0210	Yes	2 - Slightly and 3 – Moderately 3 - Moderately and 5 - Extremely
[**Learners' and trainers' attributes**]	0.0805	No	-
[**Maintenance**]	0.3273	No	-
[**Customisation degree**]	0.3878	No	-
[**Simulator sickness**]	0.4626	No	-
[**Power and battery**]	0.4574	No	-
[**Training task goals**]	0.8477	No	-
[**Interoperability**]	0.0008	Yes	2 - Slightly and 3 – Moderately 2 - Slightly and 4 – Very 2 - Slightly and 5 - Extremely
[**Flexibility**]	0.8143	No	-
[**Realism/fidelity**]	0.1443	No	-
[**Self-learning**]	0.7700	No	-
[**Institutional infrastructure**]	0.3150	No	-

Table III-4. Change of Average Rating and Standard Deviation from Questionnaire 1 to 2 for factors with high variance (Standard deviation > 1)

	Average Rating		**Standard Deviation**	
	Questionnaire 1	Questionnaire 2	Questionnaire 1	Questionnaire 2
[Size of cohort]	3.64	3.40	1.28	0.70
[Learners' and trainers' attributes]	3.79	3.80	1.25	0.92
[Maintenance]	4.14	3.80	1.23	0.79
[Customisation degree]	3.93	3.60	1.21	0.70
[Simulator sickness]	3.86	3.90	1.17	0.99
[Power and battery]	3.36	2.80	1.15	0.92
[Training task goals]	3.71	4.00	1.14	0.67
[Interoperability]	4.00	2.90	1.11	**1.20**
[Flexibility]	4.14	3.80	1.10	**1.03**
[Realism/fidelity]	3.86	3.50	1.03	**1.18**
[Self-learning]	3.93	3.80	1.00	0.63
[Institutional infrastructure]	4.07	4.10	1.00	0.57

Table III-5. Overall Average Rating and Standard Deviation of all Decision-Making Criteria Factors (Descending Standard Deviation)

Factor Category	Factor	Average Rating	Standard Deviation
Technology	[**Interoperability**]	2.90	1.20
Training	[**Realism/fidelity**]	3.50	1.18
Technology	[**Flexibility**]	3.80	1.03
Training	[**Immersion**]	3.71	0.99
Institutional	[**Public policies, standards, and commitment**]	3.71	0.99
Training	[**Simulator sickness**]	3.90	0.99
Technology	[**Motion constraints**]	3.50	0.94
Training	[**Learners' and trainers' attributes**]	3.80	0.92
Technology	[**Power and battery**]	2.80	0.92
Technology	[**Controllers**]	3.21	0.89
Training	[**Level of enjoyment**]	4.14	0.86
Institutional	[**Data security and ownership**]	4.43	0.85
Institutional	[**Space requirements**]	3.57	0.85
Institutional	[**Organisational culture**]	4.07	0.83
Technology	[**Maintenance**]	3.80	0.79
Training	[**Alignment/sequence within other scheduled teaching activities**]	4.14	0.77
Training	[**Need for intervention**]	3.86	0.77
Institutional	[**Justification of investment**]	4.14	0.77
Training	[**Task instructions**]	4.50	0.76
Institutional	[**Upfront and ongoing costs**]	4.29	0.73
Training	[**Speed**]	3.79	0.70
Training	[**Size of cohort**]	3.40	0.70
Training	[**Customisation degree**]	3.60	0.70
Training	[**Teaching/pedagogic approach**]	4.00	0.68
Training	[**Ease of repeatability**]	4.00	0.68
Training	[**Training task goals**]	4.00	0.67
Technology	[**Tracking and display accuracy**]	4.14	0.66
Institutional	[**Technical and educational support**]	4.43	0.65
Training	[**Level of engagement**]	4.36	0.63
Training	[**Self-learning**]	3.80	0.63
Training	[**Feedback**]	4.07	0.62
Training	[**Interaction**]	3.93	0.62
Technology	[**Weight**]	3.71	0.61
Training	[**User data recording**]	4.21	0.58
Institutional	[**Institutional infrastructure**]	4.10	0.57
Training	[**Task type**]	4.00	0.55
Training	[**Objective usability**]	4.00	0.55
Training	[**Perceived usefulness**]	4.14	0.53
Training	[**Ease of adoption**]	4.57	0.51

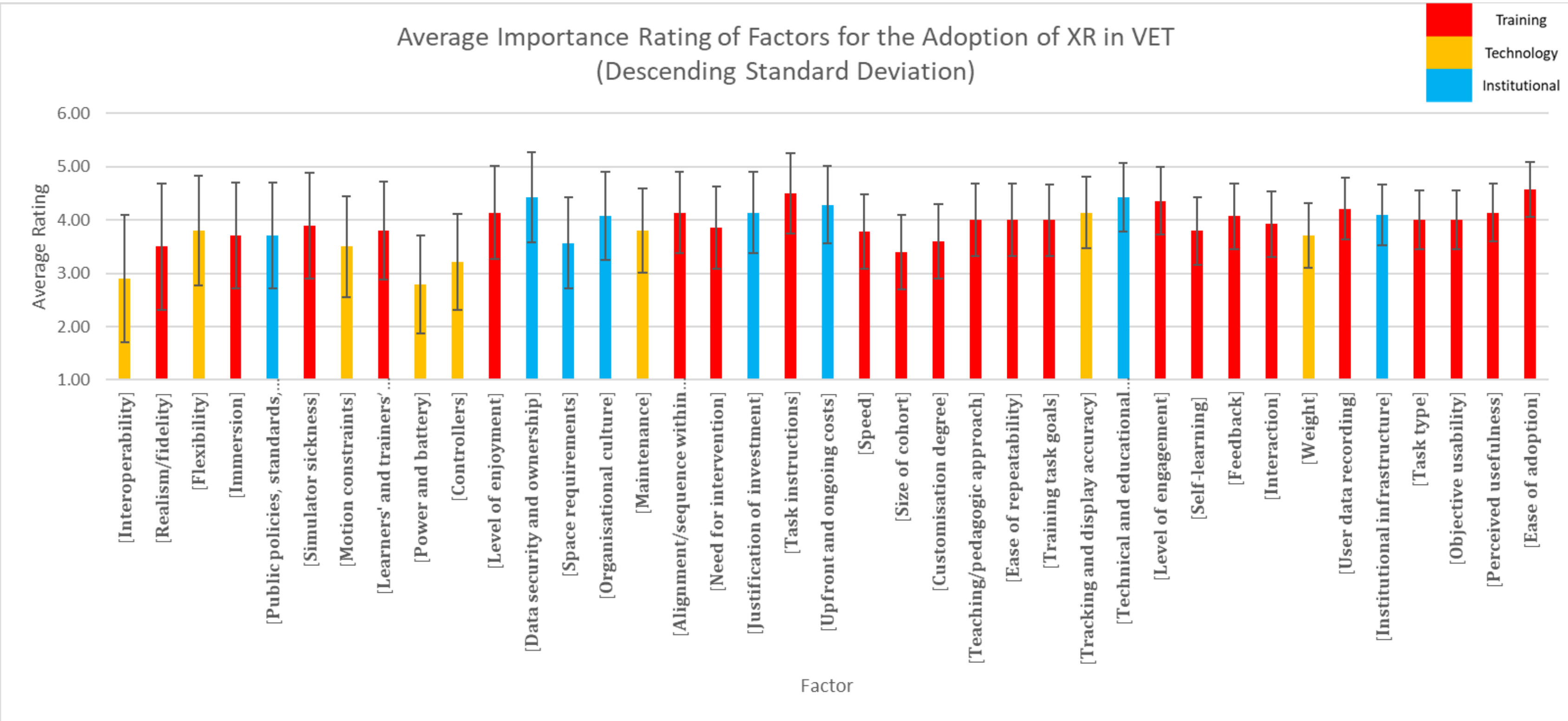

Figure III-20. Average Rating and Standard Deviation of all Decision-Making Criteria Factors (Descending Standard Deviation)

Table III-6. Overall Average Rating and Standard Deviation of all Decision-Making Criteria Factors (Descending Average Rating)

Factor Category	Factor	Average Rating	Standard Deviation
Training	[Ease of adoption]	4.57	0.51
Training	[Task instructions]	4.50	0.76
Institutional	[Data security and ownership]	4.43	0.85
Institutional	[Technical and educational support]	4.43	0.65
Training	[Level of engagement]	4.36	0.63
Institutional	[Upfront and ongoing costs]	4.29	0.73
Training	[User data recording]	4.21	0.58
Training	[Level of enjoyment]	4.14	0.86
Training	[Alignment/sequence within other scheduled teaching activities]	4.14	0.77
Institutional	[Justification of investment]	4.14	0.77
Technology	[Tracking and display accuracy]	4.14	0.66
Training	[Perceived usefulness]	4.14	0.53
Institutional	[Institutional infrastructure]	4.10	0.57
Institutional	[Organisational culture]	4.07	0.83
Training	[Feedback]	4.07	0.62
Training	[Teaching/pedagogic approach]	4.00	0.68
Training	[Ease of repeatability]	4.00	0.68
Training	[Training task goals]	4.00	0.67
Training	[Task type]	4.00	0.55
Training	[Objective usability]	4.00	0.55
Training	[Interaction]	3.93	0.62
Training	[Simulator sickness]	3.90	0.99
Training	[Need for intervention]	3.86	0.77
Technology	[Flexibility]	3.80	1.03
Training	[Learners' and trainers' attributes]	3.80	0.92
Technology	[Maintenance]	3.80	0.79
Training	[Self-learning]	3.80	0.63
Training	[Speed]	3.79	0.70
Training	[Immersion]	3.71	0.99
Institutional	[Public policies, standards, and commitment]	3.71	0.99
Technology	[Weight]	3.71	0.61
Training	[Customisation degree]	3.60	0.70
Institutional	[Space requirements]	3.57	0.85
Training	[Realism/fidelity]	3.50	1.18
Technology	[Motion constraints]	3.50	0.94
Training	[Size of cohort]	3.40	0.70
Technology	[Controllers]	3.21	0.89
Technology	[Interoperability]	2.90	1.20
Technology	[Power and battery]	2.80	0.92

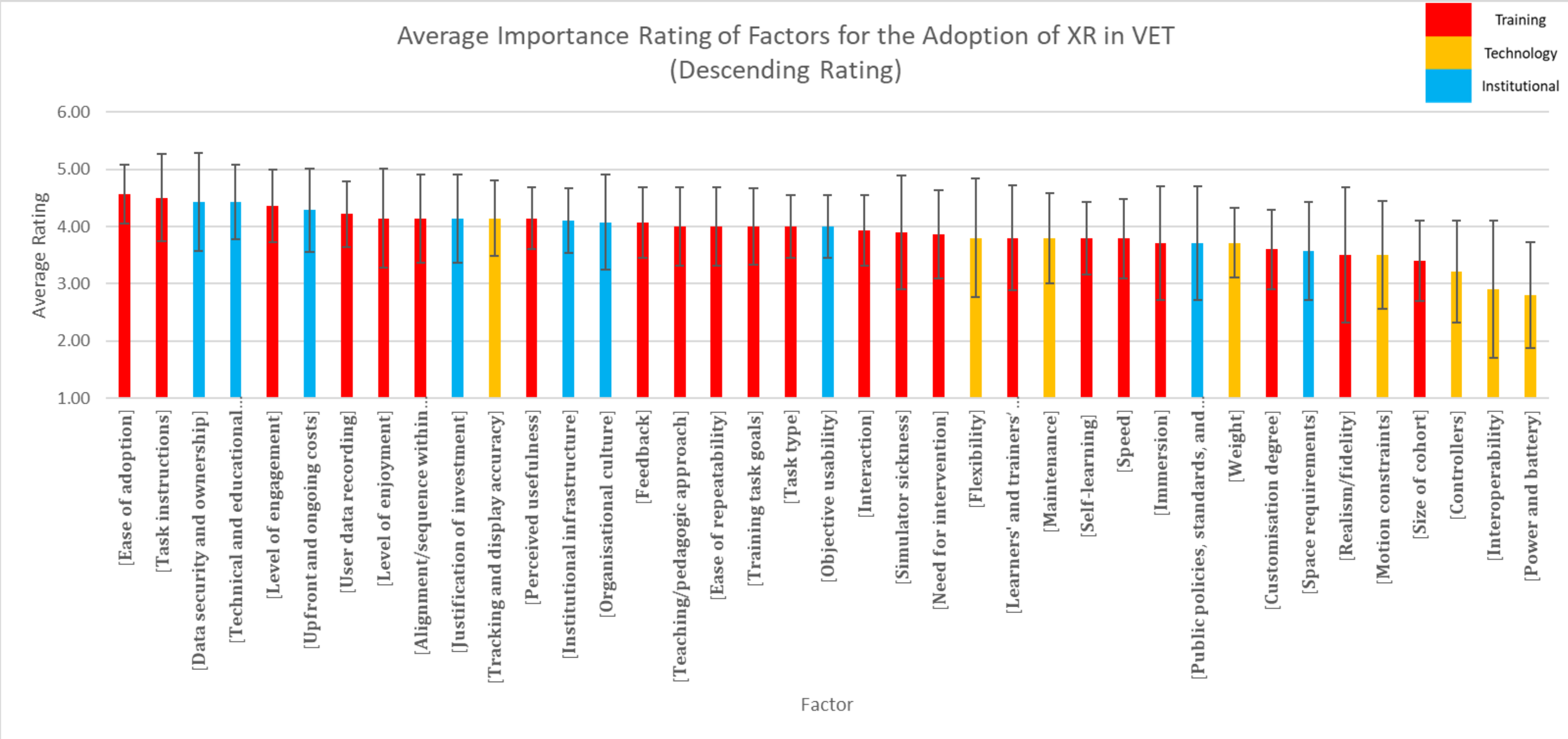

Figure III-21. Average Rating and Standard Deviation of all Decision-Making Criteria Factors (Descending Average Rating)

Table III-7. Overall Average Rating and Standard Deviation of all Decision-Making Criteria Factors (Descending Standard Deviation – Factor Grouped)

Factor Category	Factor	Average Rating	Standard Deviation
Institutional	[Public policies, standards, and commitment]	3.71	0.99
Institutional	[Data security and ownership]	4.43	0.85
Institutional	[Space requirements]	3.57	0.85
Institutional	[Organisational culture]	4.07	0.83
Institutional	[Justification of investment]	4.14	0.77
Institutional	[Upfront and ongoing costs]	4.29	0.73
Institutional	[Technical and educational support]	4.43	0.65
Institutional	[Institutional infrastructure]	4.10	0.57
Technology	[Interoperability]	2.90	1.20
Technology	[Flexibility]	3.80	1.03
Technology	[Motion constraints]	3.50	0.94
Technology	[Power and battery]	2.80	0.92
Technology	[Controllers]	3.21	0.89
Technology	[Maintenance]	3.80	0.79
Technology	[Tracking and display accuracy]	4.14	0.66
Technology	[Weight]	3.71	0.61
Training	[Realism/fidelity]	3.50	1.18
Training	[Immersion]	3.71	0.99
Training	[Simulator sickness]	3.90	0.99
Training	[Learners' and trainers' attributes]	3.80	0.92
Training	[Level of enjoyment]	4.14	0.86
Training	[Alignment/sequence within other scheduled teaching activities]	4.14	0.77
Training	[Need for intervention]	3.86	0.77
Training	[Task instructions]	4.50	0.76
Training	[Speed]	3.79	0.70
Training	[Customisation degree]	3.60	0.70
Training	[Size of cohort]	3.40	0.70
Training	[Teaching/pedagogic approach]	4.00	0.68
Training	[Ease of repeatability]	4.00	0.68
Training	[Training task goals]	4.00	0.67
Training	[Level of engagement]	4.36	0.63
Training	[Self-learning]	3.80	0.63
Training	[Feedback]	4.07	0.62
Training	[Interaction]	3.93	0.62
Training	[User data recording]	4.21	0.58
Training	[Task type]	4.00	0.55
Training	[Objective usability]	4.00	0.55
Training	[Perceived usefulness]	4.14	0.53
Training	[Ease of adoption]	4.57	0.51

Table III-8. Overall Average Rating and Standard Deviation of all Decision-Making Criteria Factors (Descending Average Rating – Factor Grouped)

Factor Category	Factor	Average Rating	Standard Deviation
Institutional	[Data security and ownership]	4.43	0.85
Institutional	[Technical and educational support]	4.43	0.65
Institutional	[Upfront and ongoing costs]	4.29	0.73
Institutional	[Justification of investment]	4.14	0.77
Institutional	[Institutional infrastructure]	4.10	0.57
Institutional	[Organisational culture]	4.07	0.83
Institutional	[Public policies, standards, and commitment]	3.71	0.99
Institutional	[Space requirements]	3.57	0.85
Technology	[Tracking and display accuracy]	4.14	0.66
Technology	[Flexibility]	3.80	1.03
Technology	[Maintenance]	3.80	0.79
Technology	[Weight]	3.71	0.61
Technology	[Motion constraints]	3.50	0.94
Technology	[Controllers]	3.21	0.89
Technology	[Interoperability]	2.90	1.20
Technology	[Power and battery]	2.80	0.92
Training	[Ease of adoption]	4.57	0.51
Training	[Task instructions]	4.50	0.76
Training	[Level of engagement]	4.36	0.63
Training	[User data recording]	4.21	0.58
Training	[Level of enjoyment]	4.14	0.86
Training	[Alignment/sequence within other scheduled teaching activities]	4.14	0.77
Training	[Perceived usefulness]	4.14	0.53
Training	[Feedback]	4.07	0.62
Training	[Teaching/pedagogic approach]	4.00	0.68
Training	[Ease of repeatability]	4.00	0.68
Training	[Training task goals]	4.00	0.67
Training	[Task type]	4.00	0.55
Training	[Objective usability]	4.00	0.55
Training	[Interaction]	3.93	0.62
Training	[Simulator sickness]	3.90	0.99
Training	[Need for intervention]	3.86	0.77
Training	[Learners' and trainers' attributes]	3.80	0.92
Training	[Self-learning]	3.80	0.63
Training	[Speed]	3.79	0.70
Training	[Immersion]	3.71	0.99
Training	[Customisation degree]	3.60	0.70
Training	[Realism/fidelity]	3.50	1.18
Training	[Size of cohort]	3.40	0.70

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