The potential of extended reality in welding training in the UAE – opportunities and challenges

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2023

Statement of Authenticity

I confirm that this DBA thesis research was performed autonomously by myself using only the sources, aids and assistance stated in the report, and that quotes are readily identifiable as such.

SAEED ALHAJRI

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Abstract

This thesis examined the impact of using extended reality (XR) technologies in the training of welding in the United Arab Emirates (UAE). The study aimed to identify the opportunities and challenges associated with the application of XR technologies in welding training. The research provides a critical insight into how welding training in the UAE can be conducted by identifying both the limitations and benefits of traditional and technology-based welding training methods. The study was designed to answer the following research questions: research question one: *what are the challenges and opportunities of implementing extended realities technologies in a vocational education setting in the UAE*?, research question two: *how does the students learning experience change when implementing extended realities technology in vocational education in the UAE*?, research question three: *what is the instructor / trainers experience of implementing extended realities technology in vocational education in UAE?*

The research methodology utilized a qualitative approach that adopted an action research strategy, which involved 18 participants in the main study, 12 apprentices and 6 instructors. The research method used two inductive strategies, semi-structured interviews for the instructors and a series of focus groups for the apprentices, which were embedded into the action research methodology.

The findings of the study showed that a hybrid training approach where the learner was trained on using traditional welding equipment together with the use of XR welding training methodology could potentially improve the welding training experience. However, while the XR welding simulators can benefit and enhance welding training, this study contends that this technology cannot completely replace traditional welding training when teaching apprentices The research concludes that the integration of XR technology along with the traditional welding equipment to train apprentices to weld in the UAE can contribute to the improvement of the quality of welding education, make the training process more efficient, improved the learner's experience and attitude to engage in attaining the necessary skills, reduced resource wastage, while providing more time for both the apprentices and the instructors which can enhance the overall learning acquisition in the UAE. ,The study however has its limitations such as the number of participants in the study, which although cannot prove that the outcomes of the research can be effectively applied beyond this study's technical college, the findings have provided a new and unique insight into how technology and traditional methods can be effectively use.

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Abbreviations

TVET	Technical and Vocational Education and Training
VR	Virtual Reality
AR	Augmented Reality
MR	Mixed Reality
XR	Extended Reality
3D	Three Dimensions
HMD	Head-Mounted Displays.
CAVE Systems	Computer Assisted Virtual Environment
CAD	Computer Aided Design
VIEW	Virtual Interface Environment Workstation
Avatar	Associative Visual Artefact to Assist Recognition
CG	Computer Graphics
TEL	Technology Enhanced Learning
E-learning	**E** Learning
VE	Virtual environment.
IT	Information Technology
ICT	Information and Communication Technology
UAE	United Arab Emirates
GCC	Gulf Cooperation Council
KHDA	Knowledge Human Development Authority
USD	United States Dollar
Apps	Applications
NASA	National Aeronautics and Space Administration
IOS	Internetwork Operating System
GMAW	Gas Metal Arc Welding
GB	Giga Byte

Chapter One
Introduction

1.1 Chapter Overview

This Chapter will present an introduction and background to the study which is focused on investigating the potential usage of using XR technologies in welding training apprentices in the UAE. The Chapter will also provide an overview and background to the current debate as to traditional vocational education, before setting out the rationale for the research. In addition, the Chapter will present a research problem statement, together with the central aim and objectives of the research. Finally, the Chapter will provide an overview of the remaining chapters in this study.

1.2 Introduction and background

Technology has arguably increasingly become an influential part of education (Olshannikova, Ometov, Koucheryavy, & Olsson, 2015). Huang, Liaw, and Lai (2016) noted that the learning and educational system including vocational training has shifted from a reliance on books, pencils, and pens to the application of interactive technologies that can help the learner to acquire knowledge more effectively than traditional methods. Nevertheless, studies such as Yilmaz (2016) and Liou, Yang, Chen, and Tarng (2017), have contended that the incorporation of technology-based learning approaches into an education and vocational setting cannot solve all the problems which exist in traditional education methods despite its ability to improve the quality of how a learner can acquire the necessary skills and knowledge. Olshannikova et al. (2015) contended that technology-based learning, together with other mediums such as multimedia has the potential to alter the traditional learning style of the individual, change the learning environment, and to be a platform where the instructor and the learner can participate without the traditional restriction of location and time. At the same time, there has been a drive towards more innovative approaches to education and learning with advancements in 3D visualisation technologies, computer hardware, and a growing range of educational programs and training materials which utilise virtual reality (Olshannikova et al., 2015). For Huang et al. (2016) virtual reality technology can be employed as a potential educational and training tool which can mitigate potential safety issues, be cost-effective while also being able to monitor the learner's progress in real time. Olshannikova et al. (2015) earlier stated that the virtual reality environment has the potential to improve the quality of the learning experience, by providing the learner with a

realistic and interactive environment. However, while there is academic evidence to indicate the potential benefits, there is still a need for further research into extended reality technology application in an educational and learning setting, particularly as the perspective of Olshannikova et al. (2015), have been challenged by Yilmaz (2016) and Huang et al. (2016) who argued that technology-based learning and extended reality technologies might alter the relationship between the tutor or instructor and the learner, as the traditional environment provides a setting where both parties are able to interact and communicate whereby creating an interactive personal environment. Ma and Nickerson (2006) highlighted that in practical training the interactive relationship of the learner and instructor was an important aspect of vocational education, and there was a need for a separation from instruction using theoretical methods. For Ma and Nickerson (2006) the acquiring and obtaining practical skills particularly in a vocational setting was vitally important for the new knowledge to be gained. To achieve this, Ma and Nickerson (2006) advocated that vocational workshops must be equipped and furnished with specialised machinery, tools and equipment for the learner to practice, as there was a need for the trainees to practice and hone their skills and techniques. However, the importance associated with skills training and the need to gain experience on technical and vocational courses has always been a challenge due to multiple constraints such as cost and time. This has also been compounded by the rapid shift recently in vocational education of seeking and adopting a constructivist pedagogy which emphasises the importance of knowledge gained through experience (Feisel & Rosa, 2005). This shift has resulted from the increased demand from business and industry for skilled technical graduates equipped with both theoretical knowledge and practical hands-on skills (Corter et al., 2007). To achieve this demand from business and industry, Gennrich et al. (2018) contended that vocational education and training (TVET) needs to apply formal or informal training methods to the learning strategies to enable the learner to acquire the knowledge and skills needed for the profession. While welding is associated with manufacturing training, this form of vocational learning has also begun to embrace the fourth industrial revolution, known as Industry 4.0, and Manufacturing 4.0, where the training of welding skills has become part integrated into the Internet of Things (IoT), Industrial Internet of Things (IIoT), and with the use of artificial intelligence (AI) (Ero et al., 2016; Lu, 2017). To emerge from this technological revolution has been extended reality (XR) which includes the creation of a real setting in a virtual environment, where there is an interaction between the individual and technology by generating a computer environment. XR technology as a technological solution consists of virtual reality (VR), mixed reality (MR) and augmented reality (AR), but in this

study extended reality (XR) will be used to group these technologies together. Below in Figure 1.1 shows the reality-virtual continuum advocated by Milgram and Kishino (1994).

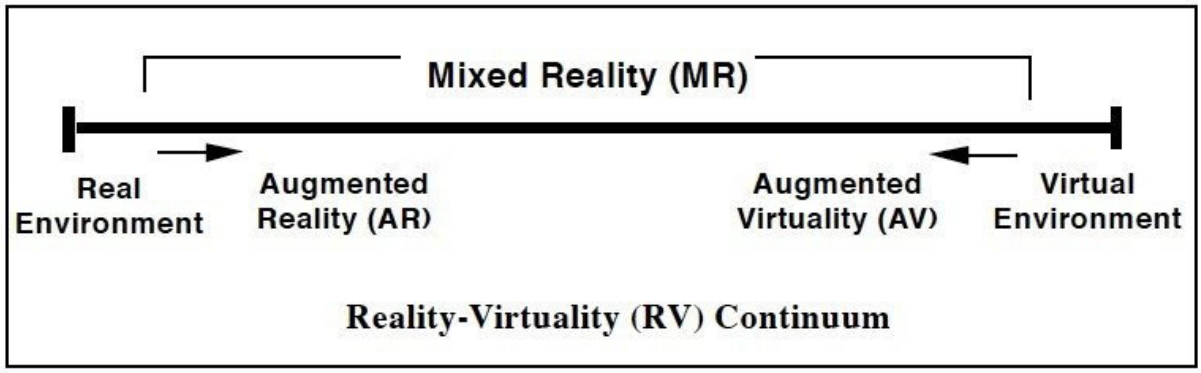

Figure 1.1. Reality-Virtuality (RV) Continuum as adapted from Milgram and Kishino (1994)

The model illustrates how the adaptation of technology and reality can be used from a real and virtual environment, and how there may be a solution for training which is hybrid. Reflecting above, in this study, the central purpose of the study is to investigate whether integrating extended reality (XR) technology can be potentially integrated into vocational welding training in the United Arab Emirates.

1.3 Definition of Augmented Reality (AR), Virtual Reality (VR) and Extended reality (XR).

Shah et al. (2019) contended that technological advancements have recently enabled the creation of virtual worlds. This has led to enhancements in the creation of virtual scenarios, with real-world objects now existing beyond the confines of the physical reality. Pandya et al. (2020) argued that virtual reality (VR) and augmented reality (AR) have the potential to revolutionise individuals' perceptions in areas including entertainment, education, and health care services. However, Kundalia, Patel, and Shah (2020) defined AR, which is sometimes referred to as mixed reality, as being the projection of virtual objects onto the physical environment that incorporates the individual's sensory experiences. This technology typically involves the use of mobile devices or smart glasses, which enable the user to see and interact with virtual objects that are seamlessly integrated into their sensory surroundings. Chavan (2016) indicated that virtual reality has become a fully immersive experience in a computer-generated world. In this reality, the user is immersed in these virtual surroundings and accepts them as being real.

This distinction between AR and XR is critical in understanding virtual technology, as noted by Çöltekin et al. (2020). Çöltekin et al. (2020), contended that extended reality is an

umbrella term that encompasses both VR and AR, which enables the realities of the physical and virtual worlds to exist. As a terminology, XR is increasingly being used to group these two technologies together by recognizing the potential for hybrid environments that blends the physical and digital experiences. Based on this, this study will refer to this technology as an AR/VR, when investigating the experiences of welding for the apprentices to weld.

1.4 Research problem

The United Arab Emirates (UAE) is considered as being one of the most developed countries in the region (Shanti et al., 2021), but higher education including vocational training is still seen as a comparatively new academic structure. Higher education commenced in 1977 with the establishment of The United Arab Emirates University, the first university in the country, which then led to the recognition that there was a shortage of skilled vocational workforce. This has led to the UAE to depend on expert immigrant workforce, which has recently changed by the new vision for the country. In 2006, the Government of the UAE set out a vision of developing a skilled workforce to meet the labour market demand, which led to the establishment of National Institute for Vocational Education. This organization was tasked to provide a customized and high-quality vocational education training. Since its inception, the majority of the vocational training courses related to welding have been conducted in a workshop environment, with a 25% theoretical and 75% practical emphasis. With this focus on practical activities, there is a need to have sufficient resources to teach vocational subjects, and instructors. This focus on practical emphasis, it has been reported by technical education institutes have consistently come under lots of pressure to deliver effectively practical sessions, which has led to this study's aim.

1.5 Aim

To investigating the potential benefits and challenges of implementing extended reality technologies in a technical educational setting in the UAE when training apprentices in welding.

1.6 Research objectives

- To achieve the aim, the following research objectives were set out:

Based on the existing knowledge set out in the literature review, **objective one**:

- To critically analyse and evaluate associated challenges and opportunities of implementing extended reality technologies in vocational education in the UAE.
- From the findings of the study, focused on the learner's experience, **objective two:**
- To critically evaluate the student's learning experience when implementing extended reality technologies in vocational education in the UAE.

Drawing on the findings related to the instructor's, **objective three:**

- To critically evaluate the instructor training experience when implementing extended reality technologies in vocational education in the UAE.
- Finally, based on the findings and discussion, **objective four:**
- To give a recommendation on overcoming the challenges faced in exploiting the opportunities of extended reality technologies in vocational education in the UAE.

1.7 Motivation behind the study

Before proceeding it is necessary to set out the professional motivation of this business doctorate study. There have been several studies (e.g., Jerarld, 2016; Jensen & Konradsen, 2018) who have highlighted the positive aspects of extended reality (XR) technology in different fields of education including in a vocational setting. This has included medical training where the learner is able to perform and perfect complex procedures without endangering the life of patients while enabling the learner time to practice before performing the procedure in real-life. This application in a medical setting was also studied by Pottle (2019), who investigated the significance of adopting XR in the medical education setting. Pottle (2019) found that training in XR had the potential to be more than just an additional solution to the current training methods, as the benefits were significantly more than the disadvantages. There have also been studies (e.g., Beaubien & Baker, 2017) which have explored the potential of XR technologies in more vocational practical educational settings. Beaubien and Baker (2017) indicated that training through a technological solution has shown potential benefits including improving training outcomes. This was supported by Lavrentieva et al. (2020) who conducted a study which evaluated the benefits of using extended reality in the welding vocational

training, however neglected and rejected the usage of traditional and conventional training methods. Earlier Cabero-Almenara et al. (2019) found that XR could improve educational outcomes and the learner's performance, while in a meta-analysis study, Angel-Urdinola et al. (2021) evaluated how extended reality training could improve the learning and skills development of the learner.

However, there has also been other studies including Johnston, Khan, and Ophoff (2019) who have challenged the benefits of training using XR technology, contending that the learner may encounter usability and technical issues which can impede their learning experience. Combined with this was the acknowledgement that the virtual and real objects are often different, and the learner may become confused as to how to perform the tasks if the learning is technology-centric only.

Based on this lack of consensus, and the fact that the UAE is currently encouraging the vocational educational sector to embrace XR technology, the study was driven by wanting to understand the potential benefits and limitations of how an apprentice and instructor experiences training how to weld in a traditional and technological-based setting, and whether XR can replace the traditional mode of learning.

1.8 **Study structure**

This section will outline the structure of the remaining chapters of the study. The next chapter, Chapter Two will provide a contextual critical insight into vocational education, with a specific focus on the UAE, and how the TVET sector can achieve the country's Vision 2030 of becoming a knowledge-based economy. The chapter will set out the facets and context of vocational training and the associated skills and learning methodologies used. The basis of this will be centred on the recent academic debate and interest in the emergence of technologies such as extended reality, which can be used to train other vocational skills, such as the assembling of furniture (Zauner, Haller, Brandl, & Hartmann, 2003), or for teaching an apprentice how to paint a car (Bacca, Baldiris, Fabregat, Kinshuk, & Graf, 2015). To emerge from the chapter is whether to train an apprentice to weld, which is a vocational skill, can be effectively attained through technology which is part of the UAE's focus on transforming the country into a high-tech knowledge-based economy (Gonzalez et al., 2018), or does the traditional vocational methodology of hands-on experience and practice have relevance still, which will be addressed in Chapter Four and Five.

In Chapter Three, there will be a comprehensive summary of the current literature, which will commence with a critical examination of the debate around the training of welding as a

vocational educational provision, before setting out the usage of conventional and extended reality. This will include how to weld has been conducted in a traditional format often learnt in a vocational training environment, including a focus on the central theme of welding and the associated debate, such as those of White et al. (2011) and Whitney et al. (2014), who highlight the need for the learner to understand how to weld through gaining or acquiring good hand-eye coordination skills. However, in a conventional welding environment there are limitations such as the challenges of providing audible feedback or the distractions of the actual setting (Du Wulf, 2007) and supported later by Boyles, (2017) that for both the learner and instructor needing to wear protective clothing (AlMahmoud, Elkonaisi, Grivna, & Abu-Zida, 2020). The chapter will then move onto critically review the usage of extended reality as a potential solution. This will include how the technology is beginning to provide a real or authentic environment where the learner is not exposed to the elements in a real welding environment (Beaubien & Baker, 2017; Lavrentieva et al., 2020), and improve cognitive and psychomotor skills (Jensen & Konradsen, 2018; Okimoto et al., 2015). However, there are potential limitations such as replicating the welding equipment, the use of XR glasses, re-creating the sparks, or not experiencing the real environment (Huang et al., 2020; Stone et al., 2013). The chapter will present a conceptual framework to summarise the current debate and gaps in existing knowledge, together with the emerging research questions, which will be used to inform the main study.

Chapter Four, the methodology chapter, will critically justify the philosophical positionality of the study, which was based on conducting a longitudinal research project. The chapter will set out the purpose of the study and how the research questions would be addressed through adopting an interventionist paradigm including the philosophical background of the research project, which are informed by the epistemology, ontology, and axiology of the study. The chapter will then present the profile of the participants, which involved 18 participants in the main study, 12 apprentices and 6 instructors, and how two inductive research approaches of using semi-structured interviews and focus groups were embedded into the action research methodology. The interview process and the protocol will then be presented including how the pilot project informed the main study, together with the research coding strategy and the codes adopted. Finally, the Chapter will identify the research limitations and how the ethical implications of conducting an interventionist study was conducted.

In Chapter Five, the findings of the longitudinal study will be presented, with a comprehensive insight into the themes found during the three independent cycles, which

generated an extensive insight based on addressing the research questions as presented in Chapter Three. The findings of the first cycle based on the traditional technique of spot welding with the tutor demonstrating the skill before enabling the apprentice with close instruction, to practice themselves on a one-to-one basis will be presented. The second research cycle's findings based on the apprentice learning through XR only will be set out. In the third cycle of the final iteration, the findings of the study will be presented where the learners underwent XR training first, followed by the session using a traditional training strategy. The findings indicated that the prevailing view was that that traditional training has substantial challenges, little engagement with the tutor or the opportunity to practice, however the usage of XR technology, the apprentice was missing the authentic real welding experience. To overcome this, there was a need to have the final cycle, the combination of both XR and traditional training provided to allow the learners not only to overcome their fear of the welding environment like the generation of sparks and electricity, but also helped them fine-tune their skills and gain more confidence in using the welding equipment.

Chapter Six will set out the critical discussion of the findings and current academic debate, which is based on addressing the research objectives. The Chapter will set out and argue that XR technology has many of the benefits associated with Pottie (2019), Smith (2019) and Lavrentieva et al. (2020), but also challenges the generalised outcomes and contends that there was a need for the learner to acquire the necessary real skills through still using conventional welding equipment as advocated by Okimoto, Okimoto and Goldbach (2015), Stone, McLaurin Zhong and Watts (2013), Papakostas, Troussas, Krouska and Sgouropoulou (2022).

Chapter Seven will present the conceptual discussion where the findings and the current debate are re-presented as an update of the original conceptual framework as presented in Chapter Three.

Finally, in Chapter Eight, the conclusion chapter will present how the research aim and the objectives were achieved, together with the contribution to business practice, integral to a Doctorate in Business Administration, of advocating a hybrid combination solution of commencing with XR technology to gain the basic or fundamental skills before learning on the actual equipment. The chapter will also set out the limitations of the study, which includes the relatively small sample size, although the study has generated a rich insight into the

learners and instructors' experiences, before setting out future research of conducting a mixed method approach.

1.9 Chapter Summary

This Chapter has provided an overview of the study through setting out a summary background of the project, which will be covered extensively in Chapter Two and Three, which informed the aim and objectives. The Chapter has also set out the professional motivation of the research project, before presenting the study's structure.

Chapter Two
Contextualised Literature Review

2.1 Introduction

This Chapter will present the current academic debate around adult learning and in particular from a vocational educational setting, including in the United Arab Emirates. This will include focusing on the limitations and challenges associated with technical and vocational education and training or the TVET sector. The chapter will then proceed to provide a critical insight into the UAE's educational provision, including the country's vocational strategy which is aligned to the Vision 2030.

2.2 Adult education

Adult education can be classified as an education that enables adults to enhance, improve, develop, and acquirement of proficient capabilities, knowledge, skills, and competencies (Tennant, 2019). This concept may also include adults who never completed traditional school, those who are looking to get an additional level of formal and informal education, and those who are looking to explore a new field as stated by Taylor, Marinau and Fiddler (2000).

Adult education has several types, including life-long learning, professional development, and vocational education. Regardless of the type, adult education plays a critical role in economic and social development, as it has been shown to increase productivity, which allows organizations to stay competitive and innovative (UNESCO, 2021).

Midtsundstad, (2019) highlighted the positive correlation between adult learning and higher employability, increased earnings, and job satisfaction. Burns, (2020) indicated that adults who engage in lifelong learning, particularly vocational training, have a higher ability to transfer their skills across different job contexts, adapting to the changing employment landscape. Furthermore, Singh et al. (2018) demonstrated how a rapid increase in private institutions, better ties to the labour market, and expansion of institutional differentiation supported economic growth.

In the UAE, the government established policies and frameworks to promote adult learning and provide opportunities for continuous education and skills development. The National Qualifications Framework (NQF) serves as a guide for the recognition of prior learning and allows individuals to acquire qualifications in a range of vocational and professional fields. Moreover, the country places great emphasis on vocational education and training to bridge the skills gap and meet the demands of the labour market (Alhajeri, 2021).

Adult education in the United Arab Emirates is not limited to traditional education settings as development programs and workshops are available for individuals to acquire new skills, enhance existing ones, and stay updated with industry trends. These programs are offered by both public and private institutions and cater to professionals across different sectors. Also, the government of the UAE recognised the importance of technology in enhancing adult learning, as the government made efforts to integrate e-learning platforms and digital technologies into adult education when the government has launched initiatives such as the "Smart Learning Initiative" and "Mohammed Bin Rashid Smart Learning Program" to provide accessible and flexible learning opportunities for adult learners (Galil, 2014).

2.3 Background to Vocational Education

Pilz and Fürstenau (2019) contended that traditional vocational education, can be seen as the methodology to develop and apply specific skills and knowledge to those in, or seeking practical roles or professions. Building on this observation, Fang and Lee (2021) stated that vocational education tends to include a broad foundation in general education together with a specialised focus on certain practical and vocational activities making the learner ready for the workplace. However, Dougherty and Lombardi (2016) in contrast evaluated transition from vocational education to career readiness among the learners and pointed out that vocational education should be viewed as more of a springboard for further study, rather than a tool simply to fast-track an individual into the workforce. For Dougherty and Lombardi (2016) vocational education is therefore a lifelong process that culminates in the acquisition of job-specific skills. From the above perspectives of Dougherty and Lombardi (2016) and Fang and Lee (2021), it is possible to conclude that vocational training is viewed as an important tool for preparing learners to gain the necessary technical skills to work effectively in the workplace, but also a means for updating the individual to acquire new skills throughout their professional life. However, for vocational education to be effective, the approach needs to reflect the learning style and approach for the learner, but this can be problematic as often the skills needed to be learnt are application-centric, which is difficult to be acquired without individualized teaching or the supervision (Sirakaya & Kilic Cakmak, 2018), a theme which be explored in the next chapter, Chapter Three.

Vocational education has had a long history dating back to 1879, when the concept was first proposed in the USA (Schenck, 1995). As to the meaning, of what is vocational education,

linguistically, ‘vocation’ comes from the word ‘Vokasi’ which means jobs, which reflects the professional sense of the activity. Interestingly, the words vocation and vocational have the same meaning, which is an education format to produce certain ‘experts’ capable of executing a specific work professionally.

In presenting the background to vocational education, Malley and Keating (2000) and earlier by Williams (1963) stated that vocational and technical education is practical orientated, in contrast to university education, which is by implication more theoretical or academic centric. Another early understanding of vocational education was that concept is more specialist, and in particular technical, in contrast to general education (Wilkinson, 1970, cited in Moodie, 2002). The earlier work of Ashby (1974) also proposed a similar distinction between education and training, or between general education and vocational education/training. More recently there has been the emergence of the technical and vocational education and training (TVET) provision which was initiated at the World Congress on TVET in 1999 in Seoul (Gamar, 2019). As a concept, TVET can be defined as the means to develop and acquire specific knowledge and skills which are required for ‘mid-level’ professions, which are more practically orientated. Therefore, vocational education includes the study of relevant knowledge which includes acquiring specific practical skills, behaviours, understanding and knowledge in certain sectors, including in welding (UNESCO, 2001). Therefore, the purpose of the TVET system is to prepare learners for technical occupations whereby they gain a proficiency in the fields which are more manual or physical in nature. Biemans et al. (2018) contends that traditional vocational training can equip the learner with the necessary skill and knowledge that will make them ready to work in technical industries. However, vocational education is also seen as a ‘fallacy’ or as being a misconception, as King and Martin (2002) noted, that vocational education and training can be a challenge between the planned and the real. This means that the educational provision cannot be simply theoretical based, as the learner needs to be fully engaged or immersed in the learning experience. This need for full engagement in the learning experience has resulted in vocational education, often following a traditional model which involves the instructor showing the individual or a small group of learners how to perform a particular task, before then practicing the newly acquired skills.

In building on this observation of fallacy or misconception, King and Martin (2002) saw it as being simply teaching the learner a specific task rather than teaching them other skills. Oketch (2007) criticized this perception of fallacy, by declaring that vocational education is considered as a form of instruction that can be used as the foundation for future training rather than simply being a means to facilitate job entry. Oketch (2007) added that vocational

training can lead to acquiring vocational-specific skills throughout an individual's lifetime. In agreeing, Abanteriba (2006) indicated apprentices can learn extensively concerning the technical aspects of their jobs through vocational education, but also acquire new skills such as working in a diverse cultural environment, which can dramatically improve the learner's employability once they graduate. Interlinked to this debate as to what constitutes vocational education, including the focus on the learner gaining vocational skills being a lifetime activity of constant updating has been increasing emphasis towards to whether there is another means of delivering this education. This has led to a series of studies in vocational education advocating the use of new technology. These studies included Zauner, Haller, Brandl, and Hartmann (2003) who developed an AR application which emulated for the learner how to assemble furniture, while later Bacca, Baldiris, Fabregat, Kinshuk, and Graf (2015) developed a technological solution to teach learners how to paint cars. Interesting, Bacca, Baldiris, Fabregat, Kinshuk, and Graf (2015) results showed that the use of technology increased the attention, precision, trust, and satisfaction amongst the learner to perform the newly acquired skills, a theme which will be critically investigated in the next Chapter.

2.3.1 Vocational Education in the UAE

As seen above, vocational education and training (TVET) emerged in the late 1980s when the UAE government responded to the labour market needs for skilled practical or vocational employees, with the establishment of technical colleges and institutions, known as the higher colleges of technology (HCT) (Wilkins, 2002). For Shanti et al. (2021) the UAE committed to vocational training, was based on the country's recognition of the importance of this form of training, to avoid the over-reliance on overseas workers. As result, the technical colleges in the UAE have been designed to enhance vocational education to provide learners with the necessary skills to enter vocational orientated professions. At the same time, the UAE government introduced a series of initiatives within the country's 2030 vision to reduce the gap in technical and vocational education and training institutes that follow traditional vocational training methods. To achieve this, the UAE government tends to improve the technical and vocational education and training system by exploring new technologies and computer-assisted educational methods to meet the growing industrial demand given the vast potential of technology. The aim is to raise the quality of technical training while reducing the time required for training (Raji, 2018). The initial growth of the HCT's in the UAE was rapid, but recently, the provision has only attracted a few hundred enrolments. Then by 2019, the colleges had only attracted approximately 4,214 students across sixteen campuses in the UAE (HCT Factbook, 2019), indicating that potential learners were not interested in entering

vocationally based professions. Earlier in 2007, the UAE also established the Abu Dhabi Vocational Education and Training Institute (ADVETI) to further promote of vocational education in the country, with a specific focus on attracting learners to enter highly skilled fields where there was high market demand. ADVETI expanded its remit to attract learners who needed to meet the admission requirements of entering the higher colleges of technology programmes after the college raised their admission criteria (Swan, 2012). However, those learners in the TVET, according to Fayyad (2022), still lack the skills and competency levels needed to either enter the workplace or meet ADVETI admission requirements.

In a series of recent studies, authors such as Raven (2018) have examined the *Emiratization* of the country's education sector and the challenges which have been encountered. For writers such as Raven (2018), the UAE educational system has attempted to modernise pedagogical concepts and incorporate more innovative teaching methods. However, as noted by Raven (2018) to achieve this, the country's education policymakers have needed to employ Western instructors to modernise the sector's system of education, which has traditionally been depended on academics and instructors from other Middle Eastern nations, like Egypt, who are culturally similar and aligned to the UAE way of learning. Raji (2019) in evaluating the UAE educational programmes, indicated that the Emiratisation strategy, although challenging, has brought about significant changes in the United Arab Emirates' vocational educational provision. For Raji (2019) the central objective of Emiratisation of having qualified Emiratis entering the vocational job market has increased. However, Gonzalez et al. (2018) in a comparative study which was a systematic literature review based on assessing previous studies into vocational programmes and how the learner experience in vocational education were being improved, contended that there were still ongoing improvements needed the United Arab Emirates. This led to Gonzalez et al. (2018) to question whether the current vocational provision in the UAE has the correct format to make the vocational training programmes suitable to engage and enrich the learner's experience for them to be proficient in the skills needed. Part of this question was also informed by the usage of technology in other countries to enhance the vocational experience, something which the UAE 2030 vision recognises as being important. Based on the insights of Raji (2019) and Gonzalez et al. (2018), this study intends to investigate whether the current UAE vocational provision can be enhanced using technological solutions, which are aligned to the country's 2030 Vision.

2.3.2 Background to the UAE vocational initiative

This section is dedicated as to setting out and presenting the background to the UAE's vision 2030 to build the country as a knowledgebase-driven economy. In achieving this vision, the UAE intends to educate the workforce to be qualified with high-skill levels, including those which are technical and vocationally orientated. To achieve this, the UAE Ministry of Education launched a strategic plan for 2017-2021 with the central purpose to build a knowledgeable and global educational provision. This new education provision was intended to target all age groups to meet the future demand of the country's labour market. The plan was based on the following values: (1) citizenship and responsibility, (2) the principles and values of Islam, (3) commitment and transparency, (4) equality and justice, (5) participation and accountability and (6) science, technology, and innovation (UAE Portal accessed February 2nd, 2022).

Among the most prominent features of the Ministry's plan and its principles is to include vocational education, which is aligned to the creating a knowledge-based economy. Since the release of this vision there have been several studies conducted, including by Pedro et al. (2019) who identified the opportunities and challenges of creating this knowledgebase-driven economy. In concluding, Pedro et al. (2019) noted that education in the UAE is beginning to reach international levels, with UAE universities beginning to be recognised as experts in the field of technology. Hamid et al. (2016) who also studied the transformation in the UAE, concluded that the UAE Ministry of Education was considering establishing innovation centres in universities while also investing in virtual and augmented reality technologies. However, the General Manager of the Abu Dhabi Educational Department (ADEK) underlined the challenges faced by the UAE in achieving the country's vision for education (Alquebaisy, 2015). Alquebaisy (2015) in explaining this, indicated that there are skills gaps, particularly around the performance of students which are below expectations, with only a small number of graduates entering the fields of science, technology, engineering, and mathematics (STEM). At the same time, there is also the reliance of overseas workers in other areas, including the construction industry. For Ashour et al. (2016), the country still needs to adopt training and education programmes which are both academic and vocational centric. In the area of vocational training, to emerge has been the reported reluctance of potential learners or apprentices entering certain vocational trades such as welding (Gonzalez et al., 2018; Gennrich et al., 2018), which if not addressed, will potential adversely affect the UAE's Vision 2030, not being fully achieved. But the question which emerges is whether part of the reason why the local Emirate nationals are not interested or prepared to seek a vocational

profession is related to the current training provision being offered, and could this offering be redesigned to make the programme and ultimately the career more interesting, which this study intended to address.

2.3.3 Bloom's Taxonomy in adult training

Bloom's Taxonomy is particularly useful in adult training, as it recognised that learners possess prior knowledge and experiences that should be considered when designing learning activities. The bloom taxonomy consists of six hierarchical levels as shown in the Figure 2.1. That increase in complexity and cognitive demand: remembering, understanding, applying, analysing, evaluating, and creating.

Bloom's Taxonomy is a widely used framework that classifies different levels of learning objectives providing educators and instructional designers with a structured approach to designing and assessing learning outcomes (Soozandehfar & Adeli, 2016).

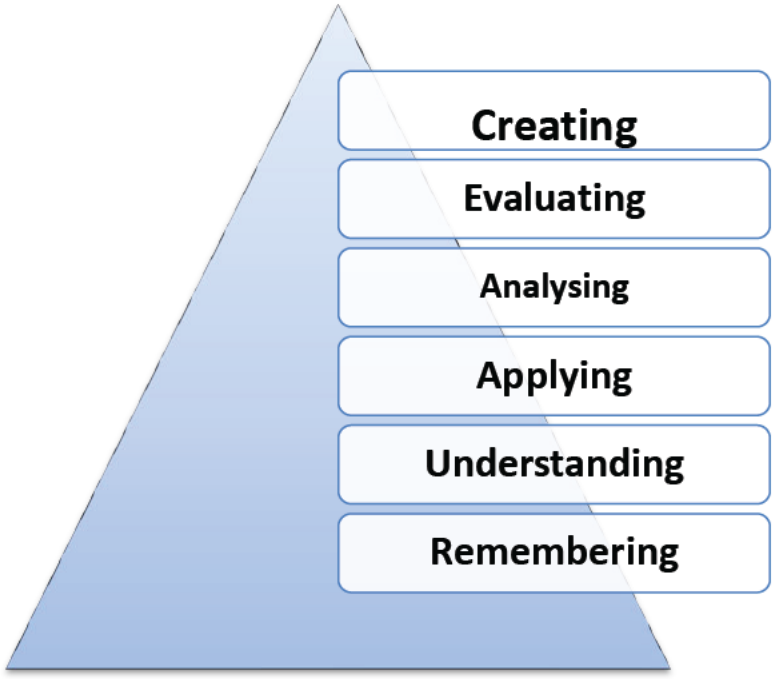

Figure 2.1 Levels of Bloom's taxonomy as adapted from AL Maani and Shanti (2023).

Starting with the lowest level, **remembering**, adult learners are encouraged to recall facts, concepts, or procedures from their memory. This is achieved by various techniques such as lectures and discussions. However, adult learners should not be limited to the recall of information but also should strive to understand the meaning. The next level is

understanding which entails the ability of learners to explain concepts, and information and then summarise it.

Moving up in the taxonomy, the **applying** level, requires adult learners to use acquired knowledge in new situations such as problem-solving or decision-making activities that require learners to be engaged actively with the material and apply it to practical scenarios to reach meaningful conclusions. The next level is **analysing**, where the learners start to use their knowledge and be able to compare, outline, integrate and begin to understand the underlying structure of knowledge to distinguish between facts and opinions.

Evaluating is the fifth level in taxonomy, it determines learners to assess the value, and effectiveness of concepts, or procedures which involve judgment, and the ability to provide reasoned opinions based on evidence and logic. Lastly, the **creating** level requires adult learners to generate new ideas, solutions, or products based on their acquired knowledge and skills. This level emphasizes the application of higher-order thinking and creativity to produce original and innovative work (Anderson & Krathwohl, 2001).

Applying Bloom's Taxonomy in adult learning ensures that learners are engaged in various cognitive processes that stimulate critical thinking, problem-solving, and creativity. Furthermore, thoughtful integration of Bloom's Taxonomy can enhance instructional design by aligning intended learning outcomes with assessment methods, instructional strategies, and the overall learning experience for adult learners.

2.3.4 Bloom's Taxonomy in vocational training in UAE

In the context of welding training, applying Bloom's taxonomy enables instructors to tailor the curriculum to the specific cognitive processes required for mastering welding techniques and safety protocols. With the framework, instructors can structure their lessons and assessments to cater to the different levels of cognitive skills required in welding. As a tool, trainers can classify the learning objectives and skills necessary for welding professionals. As a guideline, trainers can design training programs that address the different levels of thinking and skills required in welding. For the instructors the framework prescribes the structure of lesson plans and assessments to cater to the different cognitive levels of adult learners (Mello et al., 2021). Reflecting above, it is possible to suggest that Bloom's Taxonomy can be applied in welding training in the UAE, based on the following:

1. Remembering, learners to recall the fundamental concepts and terms of welding, and safety related to welding and this can be done through classrooms and practical sessions where quizzes and in-class questions can also be used to reinforce remembering to ensure knowledge is obtained.

2. Understanding, apprentices to be able to understand the principles of welding techniques, equipment, and materials as they need to fully know how they work and to be aware of potential hazards and challenges.
3. Applying, at this level, learners should have the opportunity to practice their skills in welding activities by carrying out real practice sessions on different types of materials through welding projects that require them to apply their knowledge practically.
4. Analysing, where the learners develop their ability in analysing and identifying any defect in welding projects which can be presented through visible defects in welding works and suggesting corrective actions through discussions and feedback sessions.
5. Evaluating, learners are encouraged to assess the quality of their welding activities by self-reflection and comparing their welding projects to the industrial standards.
6. Finally, creating, students should be able to show the ability to innovate and creation of new welding techniques or even perform a complex welding operation. This can involve developing advanced welding skills, experimenting with different materials or processes, and designing projects that showcase their creativity and innovation.
Implementing Bloom's Taxonomy in training welding in the United Arab Emirates could ensure that adult learners progress through different levels of learning, starting from a solid foundation of knowledge and gradually developing higher-order thinking skills. This approach promotes critical thinking, problem-solving, and creativity, ultimately enhancing the effectiveness and competency of welders in the UAE.

2.3.5 Incorporation of Bloom's Taxonomy theory in teaching welding with XR simulators.

The application of Bloom's Taxonomy theory in teaching welding skills to apprentices through extended reality technology provides a comprehensive framework for their learning and development. The taxonomy's six levels consist of remembering, understanding, applying, analysing, evaluating, and creating, which can guide the design of XR-based learning experiences for apprentices in the following.
For **remembering**, apprentices can use XR technologies to recall foundational knowledge and facts related to welding, such as equipment operation, and virtual welding techniques. Through virtual modules and guides, the learner can refresh their memory and reinforce important information.
Understanding: XR simulations enable apprentices to deepen their understanding of welding concepts and principles. The apprentice can explore the virtual environment, set up virtual

projects, and interact with realistic scenarios to gain a clearer comprehension of welding techniques.

Applying: apprentices can practice their welding skills in a virtual setting through XR technology. These simulations offer a safe environment for apprentices to apply their knowledge and hone their practical skills of gaining the required welding speed, angles, and distance. The learner can practice virtual welds, manipulate virtual welding tools, and receive real-time feedback on their progress.

Analysing: XR-based simulations allow apprentices to analyse welding scenarios and identify potential flaws or deficiencies. By practicing in this virtual environment, the learner can identify welding defects, while enhancing their analytical skills and develop their ability to troubleshoot welding issues.

Evaluating: XR technologies can provide apprentices with objective evaluation and assessment. The learner can receive real-time feedback on the quality of their welds, compare their performance against industry standards, and identify areas for improvement. Peer evaluation and comparison with expert benchmarks can also be integrated to promote further evaluation.

Creating: XR simulators can empower apprentices to experiment, innovate, and create new welding solutions. Through virtual prototyping and design capabilities, the learner can explore different materials, welding techniques, to understand complex welding projects. This fosters creativity, problem-solving, and the ability to generate original welding solutions.

By incorporating Bloom's Taxonomy theory into XR-based training, apprentices can progress through the various levels of learning while developing essential welding skills. The application of XR technologies can enhance apprentices' engagement, provide a safe learning environment, and promote critical thinking, problem-solving, and innovation in their journey to becoming skilled welders.

2.4 Chapter Summary

This study intends to investigate the potential benefits and challenges of implementing XR technologies in a technical education setting in the UAE when training apprentices in welding. To achieve this aim, this chapter has focused on providing a contextual critical insight into vocational education, with a specific focus on the UAE, and how the TVET sector can achieve the country’s Vision 2030 of becoming a knowledge-based economy. The chapter has provided an insight into the facets and context of vocational training and the associated skills and learning methodologies used. There is evidence that there has been recent academic debate and interest in the emergence of technologies such as extended

reality, which have begun to the used to train learners to acquire vocational skills, including in the assembling of furniture (Zauner, Haller, Brandl, & Hartmann, 2003), or for teaching an apprentice how to paint a car (Bacca, Baldiris, Fabregat, Kinshuk, & Graf, 2015). From this chapter, the question which emerges is whether to train an apprentice to weld, which is a vocational skill, can be effectively attained through technology which is part of the UAE's focus on transforming the country into a high-tech knowledge-based economy (Gonzalez et al., 2018), or does the traditional vocational methodology of hands-on experience and practice have relevance still?

Chapter Three
Conceptual Literature Review

3.1 Introduction

Based on the previous chapter, the contextual literature review, which has critically reviewed the background to the concept of vocational education, including in the United Arab Emirates, has set out the benefits, limitations and associated challenges in technical and vocational education and training or TVET sector. The chapter provided a contextualisation as to how these programmes have attempted to prepare a skilled national workforce, which for this study is aligned to the UAE Vision 2030 to build the country as a knowledgebase-driven economy.

Informed and reflecting on Chapter Two, this chapter will present the current academic debate around how welding can be taught using a vocational training methodology. The chapter will then present the importance of welding training by setting out the challenges and benefits associated with training the fundamentals of welding from both a trainee and instructor perspective. The literature review will then introduce the background of augmented reality (AR) and virtual reality (VR), which is also known as extended reality (XR) in the context of being used as an educational and vocational tool. This chapter will then critically address the challenges and benefits associated with extended reality (XR), specifically focusing on apprenticeship training to learn basic welding techniques. The chapter will then critically review the debate around training with XR technology versus traditional training regarding which tool can enhance and improve the learner's performance. The chapter will finally present how XR technology can enhance the learner's overall learning experience, before setting out the conceptual framework which will include the current research gaps and questions which will inform the main study.

3.2 Welding Training

While above has focused extensively on vocational education from a generalised and UAE perspective, the next section is dedicated to review the current debate surrounding welding training, which is a vocational skill. Welding is an essential component used in many sectors including the manufacture of automobiles through to the construction of buildings, pipelines and highway and motorway construction (Ali et al., 2019). But to be able to be master this vocational skill, the learner needs to be able to understand and be proficient in the

fundamental of welding, which requires extensive hands-on training sessions. Prasetyo et al. (2021) highlighted that welding, as a skilled vocational profession, is based on standards and codes, which includes the design and joining of welded parts, including following precise procedural requirements of welding, quality control and assurance throughout the process, together with the ability to use certain welding techniques. To attain the necessary skills, the most popular means is through technical or vocational training. White et al. (2011) stated that the individual to learn to weld needs to be based in a classroom environment to learn the necessary theory, and the workshop environment, for practical experience, rather than simply reliant on the workplace on-job training model.

To effectively learn to weld means that the apprentice or learner needs to acquire good hand-eye coordination skills and an understanding of how to create a strong welding bond, which can only be acquired through practice and in a safe learning environment. Whitney et al. (2014) indicated that welding requires precise adjustments to the welding travel angle, to be able to work on certain angles, use an arc length, while travelling at speed during the process, which can only be achieved initially from real-time feedback, when first learning how to gain the necessary skills. This includes visual feedback from the appearance of the weld pool and the sparks which are produced, together auditory feedback from the sound of the welding process, and haptic feedback from the feel of the welding gun. However, Du Wulf (2007) warned that the development of motor skills for apprentices during welding activities can take significant time, effort, feedback, and continuous practice to hone appropriate skills, which can be a challenge when first learning how to weld. This was supported by Ero et al. (2016), who noted the importance of cognitive skills, which can be gained through using XR technology. Therefore, for the learner to acquire the necessary welding skills the education setting needs to enable the learner to practice different techniques while also gaining invaluable feedback, which can be a challenge in a vocational setting. The question which therefore emerges is whether there are alternative solutions to enable the learner to acquire the necessary vocational skills, for example using XR. Reflecting this question, this study intends to investigate whether welding training can be learnt through using XR technology.

3.2.1 Associated challenges of training welding

While there are clear requirements and considerations which need to be understood when training an individual to weld, as set out above from a vocational setting, it is necessary to critically review the theme of welding in further depth from the perspective of the challenges faced by the trainee or learner, and from the instructor or tutor standpoint. The next section

will commence with a critical review related to the challenges encountered by the learner, before focusing on the instructor. In reviewing the current challenges, the literature review will draw on the core themes such as associated the gases and noise generated which can be off-putting for the trainee **(**Kim & Lee, 2020), and for the instructor the inability to monitor to the apprentices' progress (Agrawal & Pillai, 2020).

3.2.2 Associated challenges of training welding for the trainees

As noted above from writers including Boyles (2017) and Du Wulf (2007), there are several challenges associated with learning how to weld. From a trainee perspective, for Lombardi et al. (2005) and in a later study Lombardi et al. (2009), looking at eye protection in welding, noted one of the main challenges of training how to weld has been to ensure that those learning to weld need to have suitable safety equipment, training, and the skills and knowledge to perform the task. This includes being adequately trained in the use of protective masks and clothing while performing a particular welding activity. Golbabaei and Khadem (2015) added that proper training must also include an awareness, exposure and, ultimately, proficiency in using the different types of welding resources, such as gas, MIG, and TIG welding equipment. However, in gaining this exposure it is necessary to realise that welding workshops are typically poorly ventilated areas, which can cause substantial discomfort for apprentices when first exposed to this environment. The poor ventilation is often due to the use of CO2 gases used for welding, which, combined with the creation of sparks, ultraviolet radiation, and high heat, can make the work environment hazardous for the learner. As noted by Kim and Lee (2020), welding is a physically demanding, strenuous, and heat-related occupation, which means that personal protective equipment (PPE) is needed to be worn, but this clothing can be a further discomfort to the learner, as PPE is invariably heavy and makes breathing difficult until the individual is used to it. For AlMahmoud, Elkonaisi, Grivna, and Abu-Zida (2020) the low visibility of the welding helmet is another challenge in welding training as the learner may not be able to see their welding activity clearly.

Related to the use of PPE, is the challenge associated with the learner acquiring the necessary hand stability and eye coordination skills. As welding is a highly technical skill which requires a high level of hand and eye coordination skills, the learner needs to acquire the strength to have a stable hand movement, while also performing the task speedily at the right angle. To achieve this, the learner often needs time to practice and gain the experience to become proficient (Whitney & Stephens, 2014; Chan et al., 2022), which can be problematic if the training is with a group of other learners. Agrawal and Pillai (2020) referred to an

additional challenge that learners face during training using conventional welding equipment, which is the amount of sparks generated during the welding process, which can hinder the training experience, as initially the learner may be fearful of the sound which the high voltage of electricity makes, combined with the associated noises from the welding process or even fearful of being burnt, which could produce a detrimental and harmful behavioural response to the overall learning experience. Therefore, external facets can be off-putting to the learner, particularly in the earlier stages of the apprentices acquiring the required welding skills and may result in a negative perception towards learning how to weld. The question which emerges is whether these potential distractions can be in anyway reduced or minimised through using other methodologies to assist the learner to gain the necessary skill sets, for example through using XR technologies, which is part of this study's focus.

3.2.3 Associated challenges of training welding for the instructors

Much like the trainee, there are challenges associated with welding from an instructor's perspective. For the instructor, there are challenges unique to the trainers, but also similarities to the learners. One of the key challenges for the instructor was related to occupational safety. For an instructor, a constant concern in welding training, especially for novice learners, is associated with the hazards linked to harm to both the eyes and skin, which means that PPE must be worn. With PPE, the instructor needs to communicate through equipment not specifically designed for easy communication, which makes precise instruction and guidance difficult (Kim & Lee, 2020). Like the learner, the helmet which protects the eyes, also provides limited vision and lack of air circulation, which prevents the instructor from accurately monitoring, evaluating, and assessing the learner's progress (Agrawal & Pillai, 2020). As a result, often the instructor would not be to guide the learner until after the end of the activity had been completed, which means that the learner is progressing without the necessary correction, while also using the welding coupons and consumables incorrectly. This theme of the instructor being restricted or hampered from being able to monitor and correct the learner was supported by Da Dalto et al. (2010) who highlighted there was a need to monitor and guide the learner and provide also hands-on demonstrations. Faced with these potential challenges for the instructor, this study intends to determine whether the challenges associated with welding can be effectively trained through using other vocational methodologies.

3.2.4 Associated benefits of training welding

While there are clear challenges associated with training welding for both the learner and the instructor while using the current vocational setup, there are also benefits. The next section will specifically focus on the academic debate associated with the benefits from a learner's perspective first, before critically reviewing how conventional training can assist the instructor. The section will draw on the benefits for the learner including acquiring the necessary fundamental hands-on skills (Baharuddin, 2014), while for the instructor being able to demonstrate and contextualise the theory in practice from a vocational perspective (Weman, 2011).

3.2.5 Associated benefits of training welding for the trainees

While there a several challenges associated with welding, there are also benefits, including for the learner. Using the real equipment in training enables the learners to gain the necessary hands-on experience with the tools and machines they will be using in the workplace. This hands-on experience can be invaluable, allowing them to develop the skills and confidence needed to perform the various tasks (Kamberg, 2019). Baharuddin (2014) affirmed that TVET learners who trained on real equipment were better prepared for the working environment. In explaining this, Baharuddin (2014) contended that learners had a more comprehensive understanding of the techniques and skills needed, and therefore were able to adapt to new requirements faster. Nasir et al. (2011) and later Moro et al. (2021) further highlighted that gaining the technical skills through having hands-on experience, often meant that the learner could use the tools and work-related equipment more efficiently.

Practicing and using the conventional welding equipment enabled the apprentices to develop the necessary skills to reading and follow blueprints and technical drawings, while also learning how to use a wide range of tools and machines. Furthermore, training on real equipment can give learners the confidence to take on more responsibility in the workplace (Prasetyo et al., 2021). For Yousef et al. (2018) training apprentices with actual physical equipment enabled them to integrate theoretical knowledge with their practical experience, which could enable them to troubleshoot potential problems such as re-calibration of the welding gun which cannot be learnt from theory or from the current technological solution such as the use of XR (Troussas et al., 2022). The question therefore is whether the apprentice can gain the necessary technical skills outside of the traditional welding vocational setting, for example using a technological XR solution, which this study intends to address.

3.2.6 Associated benefits of training welding for the instructors

As seen above, training learners with conventional physical welding equipment has several advantages, but also has benefits for the instructor also. Firstly, using the actual physical equipment can provide the learner with the real experience which reinforces the theory taught to them by the instructor (Weman, 2011; Ma & Nickerson, 2006). For Ma and Nickerson (2006) practical and hands on training is vitally important for vocational training. This can include reinforcing the concepts of potential hazards associated with welding, including safety awareness, or how to use and operate the equipment more safely and confidently, while also identifying and managing any potential hazards (Wanjari & Wankhede, 2020).

From above it is possible to deduce and summarise, that training TVET students on the actual welding equipment has many benefits, as it enables the learners to gain the necessary hands-on experience with the actual resources. The learners can gain a more comprehensive understanding of techniques and skills needed, while also to be able to problem-shoot potential problems in the future. However, training on the actual equipment does have limitations, including the use of restrictive PPE, and potential waste of resources to practice on. For the instructor, there are benefits including reinforcing the theoretical content needed for welding, but also the inability or limited means to correct or guide the learner due to the equipment and the PPE needed to protect both the learner and the instructor. The role of the instructor in a vocational welding training setting is to demonstrate to the learner how to perform a particular task, then enable the individual to practice this new skill, while providing real-time feedback (Sirakaya & Kilic Cakmak, 2018). To achieve this using the conventional equipment however can be challenging for both the instructor and the trainee. Reflecting above, as to the benefits and limitations associated with training welding using conventional vocational training techniques, this study intends to investigate whether this mode of training is still beneficial from a learner and instructor perspective, or whether other methodologies such as using XR technology is more effective.

3.3 Conceptual clarifications: Augmented Reality (AR) and Virtual Reality (VR)

Leading from the current debate as to using traditional welding in a vocational setting, this section will now focus on augmented and virtual realities. For writers in the field of technological advances, such as Shah et al. (2019), Yilmaz (2016) and Yang, Chen and Tarng (2017), technology has enabled the creation of virtual worlds and the creation of real worlds which can exist through various sensory modes. Pandya et al. (2020) argued that virtual

reality (VR) and augmented reality (AR) has the potential to revolutionise individuals' perceptions of entertainment, commerce, health services, and training and education. However, it is important to note that VR and AR are also independent technological solutions. For Rauschnabel et al. (2022) AR can be defined as a projection of computer-generated elements onto the user's physical environment that incorporates sensory input such as vision or hearing. In contrast, virtual reality (VR) is a fully immersive experience in a computer-generated world (Chavan, 2016; Olshannikova, Ometov & Koucheryavy, 2015). With this fully immersive aspect, for the user, VR provides a computer-generated surrounding for the individual to be immersed in, and therefore accepts them as being real. Virtual reality and augmented reality or the term extended reality (XR), as this study will refer to them both as, have become increasingly used in North American and European educational and vocational settings, but it has yet to be embraced and adopted in the Middle East. While there is evidence that XR technology has several potential benefits, the question which emerges is whether this immersive reality can effectively replace being able to train learners to gain hands-on vocational skills, such as welding, which this study intends to investigate.

3.4 Extended reality (XR) in training

Modern technologies, such as extended reality, can be an effective vocational medium in education. In this section, the benefits, and opportunities of using extended reality technology applications will be presented from both a general perspective and in the context of this study, as to training welding. As Hancock (2009) pointed out, some learning methods can be expensive and time-consuming, particularly in vocational training where the learner needs to constantly practice, therefore, any developments or advancements in technological solutions could be beneficial. To emerge over the past decade has been the introduction of simulation-based training which has begun to be accepted as a potential means to train individual, particularly in vocational skills. Beaubien and Baker (2017) indicated that training through a simulation technology has shown potential and is gaining popularity to improve training effectiveness. In a quantitative study focused specifically on the education sector, Cabero-Almenara, Fernández-Batanero, and Barroso (2019), from a learner's perspective concluded a study on XR technologies from a university's perspective concluded that the technology enabled the increase of training performance and skills, but does can this solution be applied successfully in a welding setting?

In partly address this question, Lavrentieva et al. (2020) conducted a study which evaluated the benefits of using extended reality (XR) in vocational welding training. In support of the findings by Beaubien and Baker (2017), Lavrentieva et al. (2020) showed that

the usage of XR in training is growing and is having a significant effect on vocational training welding with the help of extended reality which can support the trainees in accelerating the transfer of knowledge and experience. In explaining this, Lavrentieva et al. (2020) noted that XR technology can be used to locate the learner in a virtual environment rather than a real and potentially harmful one, as XR training eliminates or removes the inherent hazards associated with welding, such as electrical sparks, gases, heat, and fire. In another study conducted by Rusli, Zulkifli, Bin Saad, and Yussop (2019), the authors indicated that the students when using the mobile arc welding application preferred to use new approaches to learn how to arc weld such as XR technology, particularly if the solution was incorporated into mobile technology, as their experience was not impeded by the external welding environment. However, this exclusion of the welding environment does bring into question whether this mobile technology can authentically replicate the real welding environment. Although not directly related to welding, Pottle (2019) in examining the importance of XR adoption of this technology in medicine, highlighted that training using XR has the potential to be more than just a complement to current training methods. Instead Pottle (2019) saw that the benefits of using XR technology in medical training being more beneficial than its limitations. In another study, although unrelated like Pottle (2019), Smith (2019) investigated the beneficial usage of XR by researching the episodic memory in the field of aviation. Smith (2019) found that the simulation software generated by XR technology was able to recreate the pilot experience, however there was a large associated cost needed to implement the solution, which can be a potential restriction when considering using this training methodology. This usage of XR technology was also studied earlier by Seagull, Moses, and Park (2008) in a quantitative medical based study. In the study, Seagull, Moses, and Park (2008) found that training surgical skills in virtual reality, enabled the trainers or instructors to see successful skill acquisition amongst the learners. It seems that the VR technology can simulate for the learner complex procedures, and provide detailed performance feedback. However, the VR trainers did not accept the technology as being completely suitable for their training programmes, particularly as to training basic skills, but for more complex procedures using more sophisticated physical models of physiology, XR technology was beneficial.

In a more recent study, Chakradhar et al. (2022) contended that the use of XR technology could potentially reduce the time needed for the learner to acquire the necessary skills, due to the reduction amongst learners being concerned about safety issues. The study found that the adoption of this methodology helped the learner to have a better understanding of welding techniques whereby providing them with the confidence to perform the tasks proficiently,

through the elimination of perceived risks and injury. However, the research of Chakradhar et al. (2022) was a quantitative study and neglected the experiences and perceptions of using XR reality.

While there are arguably benefits associated with XR, contradicting the studies of Pottle (2019) and Smith (2019), Nebeling and Speicher (2018), Yilmaz (2016) and Huang et al. (2016) examined the limitations of XR which included the means to re-create the actual reality for the learner to immerse into. Later Hancock and Hoffman (2021) examined these limitations of XR technologies further and concluded that the rate of technological innovation is occurring significantly faster than the speed at which a training programme can be designed, implemented, and tested, but also noted that the simulations in XR is still unable to replicate or reproduce the real environment. This included the re-creation of heat, smell and certain noises, which are often seen as key barriers to learning, resulting in adverse attitudes and behavioural traits being exhibited by the apprentices as they learn to weld. This was also supported by Cai, Liu, Wang, Liu, and Liang (2021), Cheng and Tsai (2012) and Asplund and Kilbrink (2020), who independently indicated that XR technologies potentially provided the participants with a virtual environment which could enable them to gain the necessary skills without the distractions associated with spot welding. For Asplund and Kilbrink (2020), the usage of the XR resources was an effective way of enabling apprentices to become proficient in welding as it can recreate some of the welding tasks and activities.
Therefore, XR has various advantages, which includes the advancement of re-creating the actual or real environment, whereby the learner is immersed in a safe setting, however these re-creations are still unable to fully replicate or reproduce accurately the real environment, which is a challenge for XR when used for vocational training. However, Oztemel and Gursev (2018), challenged this perspective and noted that the virtual environment was still unable to accurately replicate the real welding workshop, therefore recommended that the apprentice needed to still experience the traditional welding setting. The question which emerges is whether XR technology can effectively replicate the real vocational welding environment, which is the focused of this study.

3.4.1 Challenges of extended reality in training

While there are advantages associated with training using extended reality (XR), adopting XR in a vocational training setting also has several identified limitations. Reflecting this, this section will address the challenges associated with extended reality training in general and in the field of welding training. Santi et al. (2021) studied the adoption of XR and the related

challenges which can emerged if adopted or introduced in a training setting. Santi et al. (2021) indicated that apart from the fact that XR technology can be beneficial in the area of design and innovation, the cost associated with the technology can be restrictive in its implementing and adoption. Santi et al. (2021) also noted that XR is still not fully understood or widely accepted as an educational tool. Part of the reason for this lack of acceptance was related to the XR glasses which still need to be developed to have higher computational capabilities, better ergonomics, and durability. Finally, for Santi et al. (2021), the technology needed further advances in user-machine interfaces, including gesture and finger tracking, together with automatic setup and settings. In the area of user-interfaces and XR glasses, Fransson et al. (2020) earlier examined the challenges of head-mounted extended reality equipment. For Fransson et al. (2020) the headsets used for XR still had issues around wearability and durability.

From a European perspective, Jensen and Konradsen (2018) from the University of Copenhagen examined specifically the challenges of using the XR in education and training. Jensen and Konradsen (2018) noted that many educational resources for XR are only geared for home or self-usage like gaming, and not for educational or classroom usage. Also, for those headsets design specifically for education, the equipment required a certain degree of technical skill or IT proficiency that proved to be a challenge to instructors and learners alike. Furthermore, for Jensen and Konradsen (2018), the instructors had issues with streaming or preloading materials and user profiles, making it challenging for instructors to handle and manage more than just a couple of simulators. Furthermore, XR simulators often required periodic updates for the software, which resulted in the equipment not being available. Finally, there was a potential language issue, as most of the XR applications were in English, and English was not the main language for the learners in Jensen and Konradsen's (2018) study. The findings of Jensen and Konradsen (2018) were supportive of Fransson et al. (2020), who also noted that XR can be a significant challenge as younger learners may not understand some of the high-level of English being spoken. Bonner and Reinders (2018) in evaluating the challenges of using XR adoption in education also highlighted that it took time for the learner and the instructor to fully understand the programme and the activity needed to be performed, whether that it is a school or vocational setting.

In a similar study to Bonner and Reinders (2018), Johnston, Khan, and Ophoff (2019) concluded that users of XR technology might encounter technical and usability problems, with some learners finding XR technology and its programme too complex or not familiar

with its application. However, there was little evidence from Johnston, Khan, and Ophoff's (2019) study to suggest that usability issues are directly related to the XR technology itself but may be linked from being insufficiently technical astute to work-out or understand interface message. In fact, Johnston, Kahn, and Ovoff (2019) added that combining virtual with real objects or activities may confuse learners, as they may have difficulties associating or navigating between the virtual and the real. This brings into question whether welding apprentices when faced with a virtual reality simulator are able to readjust to using the real equipment?

Earlier Peniche et al. (2012) emphasised that with XR, there was often a difference with the real environment and the virtual one. In explaining this, Peniche et al. (2012) contended that when a trainee is faced with a real task after being immersed in a virtual training setting, performance of the learner was sometimes adversely affected as some of the skills learnt could not be exactly transferred or replicated from the virtual to the real setting. This also brings into question whether the skills gained to weld using XR can fully be transferred to the real welding setting?

In attempting to address this, McKnight et al. (2020) in studying the use of XR in medicine and surgical education, concluded that augmented reality (AR) did not have a clear benefit in terms of skills or knowledge retention compared to traditional training. Instead, McKnight et al. (2020) found that the VR learners were more likely to suffer from headaches, dizziness, and blurred vision due to the need to wear AR headgear. This theme of headgear and the limitations while explored earlier will be investigated later in this study.

From a welding perspective, there have been a few studies conducted around XR technology usage and the associated limitations or challenges. However, of note has been the studies of Shankwar and Smith (2022), Lavrentieva et al. (2019), and Mavrikios et al. (2006). Mavrikios et al. (2006) developed a VR-based prototype demonstrator for teaching learners to manually weld. The study of Mavrikios et al. (2006) found that as everything in the prototype demonstrator was virtual, the users and therefore the learners lacked the realistic sensation of holding a welding gun. Later Byrd et al. (2015) used a commercial VR welding simulator to assess existing skill levels in welders. The results of Byrd et al. (2015) showed that although the VR simulator could evaluate welding skills, it could not accurately identify an individual as an experienced or a novice welder, which indicates the role of the instructor is still important. Interestingly, as noted by Shankwar and Smith (2022), there has been no

comparative study carried out between the VR-based training system and a conventional approach using a qualitative approach. In partly addressing this gap, Feier and Banciu (2021) conducted an ergonomic comparison between real and XR torches. The study of Feier and Banciu (2021) found that the weight of the XR torches were much lighter than the real ones, therefore giving the learner the wrong impression as to reality. However, in reaching this conclusion, Feier and Banciu (2021) study did not have any educational or training component to qualify the findings, which brings into question the robustness of this identified limitation. More recently, Wells and Miller (2020), highlighted and called into question if training using XR technology to learn how to weld was effective, particularly as to whether the simulator's devices reflect the real equipment. This brought into question if XR technology was beneficial for the learner's experience.

Although clearly prior studies have demonstrated the challenges of using XR technologies in welding training, it seems that most welding simulators usage and research has been conducted around assessing existing welding skills, and not based on acquiring new techniques. Furthermore, these studies have also lacked the experiences of novice welders. Again, attempting to address this gap, Shankwar and Smith (2022), conducted a quantitative study but then called for a qualitative insight. In reaching this conclusion, Shankwar and Smith (2022), did find that novice welders can follow the visual instructions step by step and maintain a proper welding position, however, did not capture their experiences. The learner could also change the values of the welding process parameters to observe the effects on weld beads in real time in an environment, but again lacked the personal narrative of the learner. In conclusion, the study of Shankwar and Smith (2022), contended that XR-based training did provide some benefits when using XR to teach welding. These benefits included providing a solution which can help novice welders to retain welding knowledge and enhance their hands-on welding skills. However, it should be noted that the study of Shankwar and Smith (2022) was only from a quantitative perspective with an undisclosed sample size indicating the potential limitation and lack of generalisable outcome of the study. Reflecting this potential limitation of Shankwar and Smith (2022) work, this study intends to investigate the experiences and perceptions of the apprentices and instructors as to the challenges associated with using XR technology when learning how to weld.

3.4.2 Benefits of extended reality (XR) in training

Building on the identified recognised benefits as identified by Shankwar and Smith (2022), this section will critically review the current debate as to the benefits of XR technology in an

education and training setting. These benefits include making the learning experiences accessible and fun. Jerald (2016) indicated that XR simulators were first used in training, dating back to the late 1920s, when technology was in its infancy. However, while head-mounted displays (HMDs) and other XR devices have certain limitations, they can also provide several advantages and even provide a more *real* learning experience. In illustrating this, Jensen and Konradsen (2018) evaluated several studies on using head-mounted displays when used in an educational setting, and concluded there were two core benefits: improved cognitive and psychomotor skills. In reaching this conclusion, Jensen and Konradsen (2018) stated the learner can benefit from XR, through firstly the development of their cognitive skills, by stimulating attention, memory, visual processing and problem-solving. XR can also promote the learner to recall visual and spatial reasoning skills. Jensen and Konradsen (2018) then added that psychomotor abilities could be improved through an XR environment, as often the tasks or activities use tools and equipment, which enhances the individual's psychomotor skills. Finally, XR also enables the learner to practice and learn new abilities without the need for any physical resources to be prepared in advance. In a similar study, Okimoto et al. (2015) highlighted that often welders have a reduced time to practice, but with XR training, the technology can enable the learner to acquire key motor skills and then practice them in a virtual environment. Interestingly, Okimoto et al. (2015) revealed that most of the welder's training time using a conventional methodology was spent undertaking material preparation, which equated to about 70% of their total time, leaving only 30% for the welding activity or practice.

Based on above, this section indicates that XR training does provide several benefits including enabling the learner more time to practice. The XR environment also enhances and enables the development of key or core abilities such as improved cognitive and psychomotor skills, which are essential for welding. Finally, the environment can assist in the learner gaining the necessary skills and potentially experience welding in an almost real setting, however the question which emerges is how authentic or real is XR compared to the conventional approach as identified by Shankwar and Smith (2022), and Zenisek, Wild and Wolfartsberger (2021) identified as a potential weakness, which this study intends to investigate. For Zenisek, Wild and Wolfartsberger (2021) welding using inert metal gases, stick, inert tungsten gas, gas tungsten arc, gas, metal active gas and flux cored arc techniques may be hard to replicate in a virtual or extended reality environment.

3.4.3 Extended reality (XR) training versus traditional training

Following the review of the benefits and challenges associated with XR, this section will present the debate of training welding by using the conventional traditional methods versus the usage of new technology of extended reality (XR). The section will critically explore the benefits and limitations of traditional and XR training which could be used to train apprentices to weld.

Theoretical and practical classes were the primary mode of instruction in traditional education training (Meguid & Collins, 2017). In this format, Kamei et al. (2016) emphasised the importance being present in the learning environment and the need for memorising information. Research conducted by Izard et al. (2018) challenged this perspective of learning by examining XR as a tool for vocational learning compared to the traditional training mode. For Izard et al. (2018) the study found that the traditional mode of training was not as beneficial as using XR technology. However, using XR does have apparent limitations, particularly as most learners will learn at different paces, and may not grasp practical skills because of the lack of uniformity and realistic models in traditional learning settings. In support of the above, Kyaw et al. (2019) carried out research to investigate the difference learning experiences of qualified health professionals compared to those who just were commencing their studies. The results of Kyaw et al. (2019) study illustrated that modern medical education and training might benefit from new developments in digital technology. In a similar study, Maresky et al. (2019) investigated how XR had potentially improved the learner's understanding of cardiac anatomy by comparing the traditional mode of the practical element of surgery with the usage of XR. Maresky et al. (2019) concluded that XR had been effectively utilised in medical education to teach cardiac anatomy to perform certain practical activities, and improved the overall training experience compared to when trained in the traditional mode, as XR enabled the learners to wear specialised eyewear to manipulate body components virtually.

From a welding perspective, Stone et al. (2013) compared traditional welding courses to XR training. Stone et al. (2013) indicated that using integrated XR training had a similar cognitive effect on the learner compared to learning how to weld within a traditional learning setting. In illustrating this, Stone et al. (2013) demonstrated in their quantitative study the development of motor memory skills amongst learners as to using XR technology and found that this solution enabled the individual to learn particular welding techniques which were often difficult to gain using the more conventional or traditional mode. In concluding, Stone et al.

(2013) noted the different motor skills developments amongst the learners could be improved or enhanced using XR welding training. Finally, Stone et al. (2013) also showed that qualified welders could become more proficient in a considerably shorter period of time, while also reduce the consumables or resources used compared to using traditional modes of learning. However, the study was unclear as to the benefits for using XR to train beginners or novices how to weld. In a similar study, Huang et al. (2020) investigated the applicability of XR technology to assist conventional welding training. The study of Huang et al. (2020) which was based on conducting a critical review of existing articles before conducting a series of interviews with learners and instructors as to their experiences as to welding training using XR. The results of Huang et al. (2020) study showed that most learners when using XR welding technology had positively contributed to their skills level. However, while informative, the qualitative study did not research using both a conventional and XR methodologies, but instead focused on the technological solution only. In a more recent study by Papakostas et al. (2022) into AR's application into training welding, the research adopted a quantitative approach based on a modified Technology Acceptance Model focused on two external variables: perceived enjoyment and system quality, by surveying a sample of 200 trainees. The findings of Papakostas et al. (2022) study showed that the use of an AR simulator was a positive to enhance the learning experience, through its perceived system quality and its ease of use, however it lacked the real experiences and perceptions of both the learner and instructor, which this study intends to address.

From above it is possible deduce from the section, that there are potential benefits of using XR in different fields of education and training, including for training surgeons, in the field of medicine and to train welders. These studies included the possibility that XR could enable surgeons to gain and improve their skills, as the mode of instruction enabled the visualising of certain aspects of the practice which are difficult to replicate in the real world (Maresky et al., 2019). The studies above like Stone et al. (2013) and later by Huang et al. (2020), indicated that XR and virtual reality training could also benefit welding training, through enabling the learner to learn certain skills, which are difficult to be reproduced if performed using traditional training methods (Stone et al., 2013). What remains unclear from these studies is whether XR and conventional training in the field of welding can be effectively implemented, and if one of these methodologies is more dominant than the other. To achieve this, this study intends to investigate the usage of conventional and XR technological solutions by enabling the learner and instructor to experience both methodologies when learning how to weld, then capture their experiences and perceptions.

3.5 The debate as to extended reality training potential replacing traditional training in vocational training.

As noted above, there is still a gap in understanding as to whether XR can effectively replace traditional training practices. In partly addressing this, Butt (2020) studied the interrelationship between welding in the manufacturing sector, and the adoption of XR. Butt (2020) concluded that XR potentially can be cost-effective which could deliver the training content in a timely manner. To understand this perspective further from a welding context, Lavrentieva et al. (2021) examined the adoption of XR in a vocational welding training setting. Lavrentieva et al. (2021) indicated that training apprentices could potentially provide a richer education experience by using the virtual training simulator equipment, which enabled the learners to master certain welding skills faster. Price et al. (2019) earlier supported the findings of Lavrentieva et al. (2021) that XR technologies could enhance educational outcomes for learners by assessing the course progress of the individuals in a timelier manner. Similarly, Huang et al. (2020) investigated the potential for using XR technologies in welding training and confirmed that the technology provided an efficient means to learn how to weld. In an earlier study, Whitney and Stephens (2014) argued that using XR in welding training can be effective for skilled welders to learn additional welding techniques and can potentially save associated costs related to physical resources which are essential for training using the traditional methodology. However, evidence still needs to be provided if the XR technology can help train novices or beginners to weld as noted in the previous section. While these studies have indicated the benefits of using XR as a potential solution to train apprentices to weld, there are also detractors, which has included Ali, Dafoulas, and Augusto (2019) who carried out a comprehensive mapping study to evaluate the literature on collaborative educational spaces utilising XR technologies. The study of Ali, Dafoulas, and Augusto (2019) found there was a lack of research as to how beginners or novices can use a mixture of XR and traditional training methods. The study also questioned whether XR and traditional training methods can be effectively blended to provide a holistic learning experience.

Based on above, it is possible to deduce that XR technology can potentially benefit the learning experiences of the individual learner, however it is dependent on the experience of the welder (Butt, 2020). In the study of Lavrentieva et al. (2021) and earlier by Huang et al. (2020), both studies focused specifically on welding, and concluded that XR provided the means for the learner to practice without the restrictions of needing additional welding resources while also mastering new skills faster due to be ability of being able to constantly

repeat the same activity. However, while Whitney and Stephens (2014) study also confirmed this, the study only focused on experienced welders, and brought into question whether this could be applied to novice or inexperienced learners, a theme this study will investigate. In qualifying this, Ali, Dafoulas, and Augusto (2019) later noted that the lack of research into whether XR could enable the earlier learner to attain the necessary welding skills, and then questioned if a mixture of XR and traditional training methods was an effective solution, but there is a need for further investigation.

3.6 Chapter Summary

This section will present a comprehensive summary of the current literature, which will commence by critically examining the debate around the training of welding as a vocational educational provision, before setting out the usage of conventional and extended reality (XR). Much of the training and learning how to weld has been conducted in a traditional format often learnt in a vocational training environment. As a concept, vocational training tends to be orientated around enabling the learner to acquire professional hands-on skills which is in contrast to university education, as the methodology is centred on providing the learner with practical orientated activities, in contrast to being primarily theoretical or academic centric (Williams, 1963). But with this vocational orientation, the expectation is that the learner will gain both the theoretical knowledge, while also acquiring the necessary practical skills, needed to perform the required activity. This activity of learning for writers such as Dougherty and Lombardi (2016) were seen as being a lifelong process, which can culminate in the acquisition of job-specific skills. In achieving this, the traditional mode of vocational training was instructor-centric, which required the tutor to demonstrate and guide the learner through performing certain tasks and activities (Pilz & Fürstenau, 2019). This mode of learning however can be challenging for certain vocational programmes including welding.

More recently, vocational education has seen the emergent of the TVET system which is orientated around enabling the learner to acquire skills for technical occupations and professions (Biemans et al., 2018). However, this approach to vocational training has been challenged as to its relevance, as noted by King and Martin (2002) who stated that vocational training needs to be more aligned to the real activities being taught, as opposed to being theoretically studied, and where the instructor teaches the learner more than simply performing the basic task. In addressing the concerns of King and Martin (2002), Abanteriba (2006) did highlight that apprentices can learn the technical aspects of their jobs through vocational education, but also acquire new skills such as working in a diverse cultural

environment, which can dramatically improve the learner's employability once they graduate, an aspect which the UAE's Vision 2030 is wanting to achieve to make the country to become recognised as a world knowledge-based economy. To achieve this recognition, the UAE has decided to invest in the country's educational provision including in the area of vocational training, as a means to ensure that the nation is no longer dependent on overseas workers. However, as noted by Gonzalez et al. (2018), there have been a series of studies conducted as to the current progress of the UAE initiative. For Gonzalez et al. (2018), there was the question as to whether the current vocational provision in the country has the correct format to make the vocational training programmes suitable to engage and enrich the learner's experience for them to be proficient in the skills needed. Part of this question of Gonzalez et al. (2018) was informed by the usage of technology in other countries to enhance the vocational experience, and whether this would be suitable for the UAE apprentices in learning vocational skills, which is a theme this study intends to address.

As this study is focused on the current vocational training of apprentices to weld, the chapter focused on the central theme of welding and the associated theory. For writers such as White et al. (2011) to learn to weld needs the learner to be embedded in a classroom environment to acquire the necessary theory, and the workshop environment to attain the practical experience, rather than simply rely on the workplace on-job training model. In following this strategy other writers such as Whitney et al. (2014) saw the need for the learner to understand how to weld through gaining or acquiring good hand-eye coordination skills and an understanding of how to create a strong welding bond, which can only be acquired through practice and in a safe learning environment. In developing this, Whitney et al. (2014) stated that welding therefore requires precise adjustments to the welding travel angle, to be able to work on certain angles, use an arc length, while travelling at speed during the process, which can only be achieved initially from real-time feedback, which are essential requirements when initially learning how to weld. However, in a conventional welding environment, audible feedback is often hard to achieve. There was also the need for constant practice, which can be problematic when training in a conventional learning setting. This perspective of constant practice was identified by Du Wulf (2007), who also identified the limitation of the conventional environment which can potentially impact on the learner experience, due to the sparks and heat being produced, together with the associated noises of the welding environment. This is further compounded by the need for both the learner and instructor to wear protective clothing or PPE, which can be restrictive in terms of vision, audio /hearing,

and movement, which for writers such as AlMahmoud, Elkonaisi, Grivna, and Abu-Zida (2020) can impede the learning process.

To address these associated challenges, there has been the emergence of the need for an environment which minimises or removes the noise and associated distraction like heat from the training environment, which has led to writers including Lavrentieva et al. (2020) to propose the usage of extended reality (XR) as a potential solution. However, while there are clear benefits associated with XR, as noted by Lavrentieva et al. (2020) and Beaubien and Baker (2017), including how the technology is beginning to provide a real or authentic environment where the learner is not exposed to the element of the *real* welding environment, there are also limitations. For advocates of XR, like Beaubien and Baker (2017) and later by Lavrentieva et al. (2020), this technology invention enables the learner to practice techniques which are normally hard to achieve using conventional methods, then enable the individual to re-practice the skill gained afterwards, without the limitations of time and need for physical resources. For other writers including Jensen and Konradsen (2018) and Okimoto et al. (2015) who evaluated XR, identified there were improved cognitive and psychomotor skills amongst learners. In reaching this conclusion, Jensen and Konradsen (2018) found cognitive skills could stimulate attention, memory, visual processing and problem-solving through using XR. XR can also promote the learner to recall visual and spatial reasoning skills (Okimoto et al., 2015). This was illustrated by the research of Maresky et al. (2019), who studied the application of XR in a surgery setting. In concluding, Maresky et al. (2019) stated that XR could enable the surgeons to gain and improve their skills, as the mode of instruction enabled them to visualise certain aspects of the practice which would have been difficult to replicate in the real world.

However as noted above, there were also documented limitations or the restrictions associated with XR, for example the replication of the welding equipment, the use of XR glasses which can be problematic as to re-creating the sparks, or the fact that the learner is not actually experiencing the real environment, such as the noise of high-voltage electricity or associated heat, which are fundamental experiences the apprentice needs to be familiar with. The research by Huang et al. (2020) also indicated that the XR can be effectively used for experienced welder to learn new techniques but has questioned whether this solution can be used effectively for novices or beginners as to learning how to weld. This is theme of whether XR can be used to train novice apprentices will be address in this study.

Finally, there is the question posed by Stone et al. (2013), and later by Huang et al. (2020) who asked whether XR and virtual reality training could also enable the learner to acquire certain skills, as some aspects are difficult to reproduced if not performed using traditional training methods. Then added to this, is whether XR and conventional training in the field of welding can be effectively implemented, and if one of these methodologies is more dominant than the other. This study intends also to address these questions posed by Stone et al. (2013), Huang et al. (2020).

3.7 Conceptual Framework

The conceptual framework, in Figure 3.1, sets out the fundamental gaps in existing knowledge and the relationship to the aim of the study. In the framework, the relationship between the first research objective: To critically analyse and evaluate the associated challenges and opportunities of implementing XR technologies in vocational education in the UAE.

The literature review set out in two dedicated chapters, has identified two major gaps. The first gap is that although there is existing literature related to the challenges and benefits associated with using extended reality for training, there is an existing lack of academic understanding as to the challenges of adopting this technological solution in the UAE. Drawing on the existing literature, for example, Smith (2019) and Pottle (2019), these studies have shown that augmented and virtual reality can present challenges in providing training solutions, including in the area of medicine. However, while these existing studies are informative, as presented above in the chapter there has been relatively little research conducted from a UAE vocational perspective, and even less as to how this technology can be used to train apprentices to learn the fundamentals of welding. The second gap identified from the literature review, which was related to the first research objective, was that while there is increasing academic interest in the area of extended reality, which has included studies by Johnson, Khan and Ophoff (2019), there has been notably little published from a vocational UAE perspective, which this study intends to address. This gap was also aligned closely with the fourth research objective as to whether the UAE government-led initiative to become a smart technological-based economy can be successfully achieved through exploiting the opportunities of extended reality technologies in vocational education in the UAE.

The literature review revealed another gap in existing knowledge which is aligned with the second research objective: to critically evaluate the instructor training experience when implementing XR technologies in vocational education in the UAE, which is related to the actual experiences of the learner gaining vocational skills when acquired from using extended reality technology or whether traditional modes of learning are more suitable. Studies by Beaubien and Baker (2017) and Lavrentiva et al. (2020), while informative, the learner's experiences as a comparative interventionist approach have yet to be conducted. Furthermore, the learner experience of using extended reality in a UAE vocational setting is yet to be investigated, particularly in the area of behavioural changes and how effectively the learner can acquire the technical knowledge to weld successfully.

In addressing the second objective: to critically evaluate the student's learning experience when implementing extended reality technologies in vocational education in the UAE, there emerged from the existing literature two gaps as shown in Figure 3.1 below, which were also aligned with the third research objective: *to critically evaluate the instructor training experience when implementing extended reality technologies in vocational education in the UAE, emerged*. The first gap as depicted in Figure 2.1, was whether extended reality can provide a holistic learning experience and if this technology can replace traditional welding methodologies as advocated by Jenson and Konradsen (2018). The second gap (see Figure 2.1) which straddles both research objectives two and three was that although the benefits have been arguably extensively explored, what remains unclear is whether the potential challenges and benefits experienced by a learner are the same as the instructors.

Finally, in addressing the final research objective four, to give a recommendation on overcoming the challenges faced in exploiting the opportunities of extended reality technologies in vocational education in the UAE, as shown in Figure 3.1, the literature review revealed that there was limited research conducted as to whether extended reality can enable the UAE to become a strong knowledge-based economy, or does this technology also need the traditional modes of learning to enhance the apprentice's experience when learning how to weld.

In summary, this literature review has revealed there are six key gaps in existing knowledge in relation to how to train apprentices to weld using XR technology in the UAE, which are aligned to the main aim of the study which was to *investigate the potential benefits and challenges of*

implementing extended reality technologies in a technical education setting in the UAE when training apprentices in welding. Based on Figure 3.1, there emerges three key questions. The first question relates to the first and second identified gap of knowledge and also the sixth gap which is aligned to the UAE 2030 Vision. The literature review has revealed that the first gap of knowledge is that while there has been increased research into XR technology including those of Smith (2019) and Pottle (2019), who focused on different sectors application of XR technology including in medical training and more recently from a welding perspective with Lavrentiva et al.'s (2020) research, to date however, there has been minimal research conducted into determining the challenges of adopting AR/VR in teaching welding in the UAE.

This chapter in critically reviewing the current literature has also revealed that research into XR, AR/VR training, although gaining increased academic interest (e.g., Johnson, Khan & Ophoff, 2019), there has also been minimal research from the UAE vocational sector. Based on these two gaps, the following research question, **research question one** emerged: *what are the challenges and opportunities of implementing extended realities technologies in a vocational education setting in the UAE*? In addressing this gap, the study will answer **objective one**: *to critically analyse and evaluate associated challenges and opportunities of implementing extended reality technologies in vocational education in the UAE*.

To emerge from the literature review was the second research question, which was based on the third, fourth, fifth and sixth gaps, which also relates to the third research question. The third gap is that current studies including Beaubien and Baker (2017), and Lavrentiva et al. (2020), whose research studied XR application into welding training, still lacked a focus on learner's hands-on experience from learning using extended reality technology compared to using traditional methods, while the fourth gap was related to existing research by Jenson and Konradsen (2018) who indicated that technology can provide a holistic learning experience, but what remains unclear from the existing literature was whether XR can effectively replace using traditional training methodologies to teach an individual to weld. From the literature review, the fifth gap was based on the fact that past research (e.g., Jenson & Konradsen, 2018) has only focused on the benefits of introducing AR/VR in training rather than whether extended reality solutions can be effectively deployed in welding training to train future apprentices, which this study intends to address. Finally, the sixth gap is based on the UAE governmental led initiatives and the country's Vision of 2030, which is aimed at creating a strong knowledge-based economy which is driven by technological solutions. But what remains unanswered is

whether extended reality technologies can meet the nation's goals and be effectively used in vocational education.

To address the third, fourth, fifth and sixth gaps, the following research questions will be addressed: **research question two**: *how does the students learning experience change when implementing extended realities technology in vocational education in the UAE*?, while the second research question addresses the **second research objective**: to critically evaluate the student's learning experience when implementing extended reality technologies in vocational education in the UAE. Finally, the **research question three**: *what is the instructor / trainers experience of implementing extended realities technology in vocational education in UAE*? will meet the **third research objective**: to critically evaluate the instructor training experience when implementing extended reality technologies in vocational education in the UAE, which will also address the third, fourth, fifth and sixth gaps identified in the literature review.

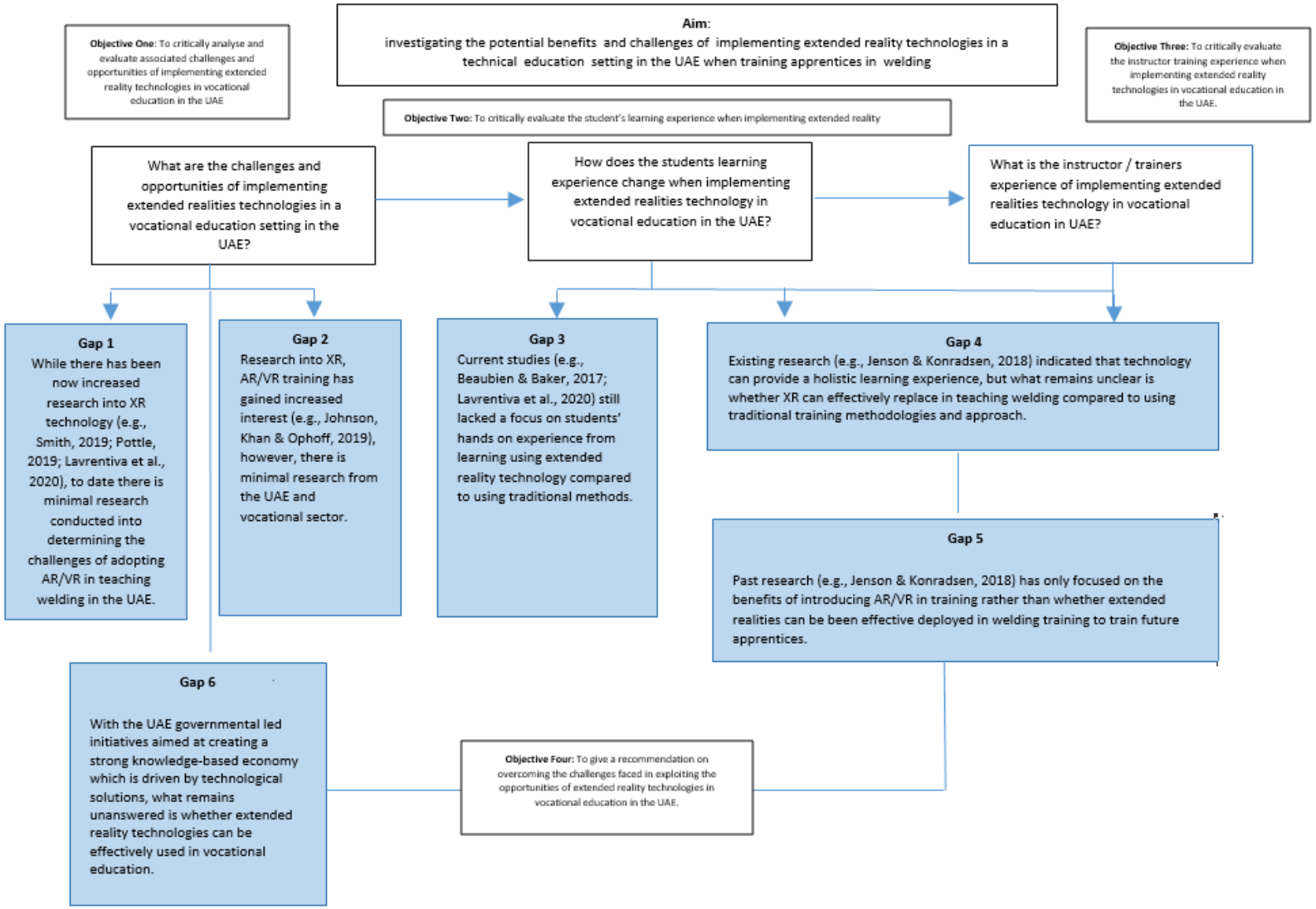

Figure 3.1 Literature review conceptual framework

3.8 Summary of Core Concepts

This chapter has set out the debate as to whether training using real equipment is beneficial to enable the apprentice to learn how to use and control the physical welding resources. This included the usage of using real gas welding equipment to understand how to re-calibrate the resource, therefore being better preparing the apprentices for the working environment. The usage of the physical welding equipment also empowered the learner in how to deal with the real hazards in the actual welding environment, which was seen as a benefit of using traditional training, a theme later used in the coding tree for theme 1, under the coding nodes 1 to 4. However, training with real equipment does have challenges and limitations. These included poor ventilation in the learning environment which can lead to an uncomfortable training experience that can hinder the apprentices to attain the necessary skills.

Another challenge to emerge from the literature was associated with training with physical welding equipment was the time needed for individualized training. Closely associated with this theme was how students were trained using the actual or real equipment, and the potential loss of confidence, when training with the physical resources. From a welding perspective, this would be related to the heat, sparks, and high-voltage noises. There was also the challenge associated with the student not being able to easily communicate with the instructor due to the necessity of having to wear the mandatory safety gear. This also limited the instructor's ability to monitor the progression of the students due to visibility issues. This theme was used to inform the study's coding tree as to the challenge of using traditional training setting, as presented in theme 2, under coding node 6. The existing literature further revealed that training with extended reality can assist the learner to acquire the necessary psychomotor skills that are essential for welding. Finally, as identified in the literature review, there was the potential benefits associated with combining training methods of XR and traditional training techniques in a technical vocational setting in the UAE, which was used to inform the coding tree, under the headings of benefits of training with XR, under the themes 4, 5 and 6.

However, in the existing literature, there was a gap of understanding as to the potential advantages of using XR to train apprentices including around welding. The current literature indicated that XR had limitations including the high investment cost, poor visibility due to using HMD glasses, and the reported confusion of the individual when transitioning from virtual to real objects. These were seen as an additional challenge associated with using XR, and whether the usage was influenced by the apprentices' familiarity, for example home and leisure usage like for gaming. This finding formed part of the coding tree as to the challenges

of XR training, as presented as theme 6, under nodes 1 to 3. Finally, as highlighted above there was limited research on the role of the instructor in vocational welding training using extended reality technologies and whether this solution can benefit or hinder welding training, which will be addressed in this study.

3.9 The importance of self-confidence in training

Self-confidence in training is a crucial characteristic that can influence the effectiveness and success of a training program and, ultimately, the learning outcome. Therefore, it is important for trainees to have self-confidence in the training received, as the delivery can influence the learner's level of motivation, engagement, and ability to apply what they have learned (Noe, 1986). When there is confidence in the training provision, the learner tends to perceive that the learning experience was positive, which then encourages trainees to ask questions and actively participate in the activity. With this active participation, the trainee often gains confidence by investing greater effort and commitment into the overall learning experience. This confidence can lead to an increase in self-efficacy beliefs, which further enhances their future learning and ultimately their performance. Where trainees possess increased confidence, the mindset of the individual learner changes, with a more focused and positive attitude toward the challenges and opportunities for future growth and development. For Smith et al. (1995), trainees who had experienced a high and positive level of confidence in their training were more likely to actively engage in the learning process and demonstrate higher levels of skill retention.

3.10 The potential of extended reality in improving self-confidence in training

Extended-reality welding simulators have emerged as a potential tool for enhancing the skills and confidence of trainees in welding (Tieri et al., 2018). By providing a realistic and immersive environment, extended reality simulators allow trainees to practice various welding techniques without the risks associated with live welding. This enhanced safety factor contributes to a greater sense of confidence among trainees, as they can explore different scenarios, make mistakes, and learn from these skills without the fear of causing damage or harm. Furthermore, XR simulators offer the opportunity for repetition and mastery, as trainees can repeatedly practice welding techniques in a controlled and simulated environment until they feel confident in their abilities. This repetitive practice helps build muscle memory and improve technique, leading to increased confidence in performing welding tasks. Additionally, XR simulators can provide instant feedback and assessment of the trainee's performance (McCloy & Stone, 2001; Chen et al., 2019). This feedback allows

trainees to identify areas for improvement and make adjustments in real-time, further boosting students' confidence in their welding skills.
In summary, confidence in training can significantly influence the success of a training program by enabling, the individual to acquire the necessary skills. To enhance this confidence, one technique is the use of extended reality welding simulators as an effective tool for enhancing the learner's self-confidence in learning how to weld. These simulators can provide a safe and immersive environment, which enables the trainees to practice and master the various welding techniques, leading to increased self-efficacy and confidence in their abilities. The question that emerges is whether these integrated XR simulators can increase the learner's self-confidence when introduced into an UAE apprentice welding training program.

3.11 The importance of engagement in vocational training

The level of learner engagement is fundamental in vocational training, as it enables the individual to gain the necessary skills, knowledge, and expertise to perform the required tasks. Where the trainee is engaged in vocational training, this does not only equip the trainee with the necessary skills and knowledge for their chosen vocation, but also enables the learner to ultimately perform the required task safely, effectively, and efficiently. To achieve this, it is important for any vocational training program to be aligned with the skills needed to perform the role effectively. Therefore, the training vocational program needs to be carefully aligned to the individual and to the required skills, but also used to enhance the trainee's career development and advancements (Haruna & Marthandan, 2017).

To assist in this engagement in vocational training, to emerge in the past decade, has been the usage of extended reality. This usage of this technology has begun to enhance engagement in vocational training by providing realistic and immersive learning experiences. This has included being able to now replicate and simulate real-world scenarios, while enabling the learner to practice skills in a safe and controlled environment. Through this technology, the learner can build their confidence and competencies as the learning occurs virtually. This means that the learner can fully engage with the task without being concerned about the real-life consequences of making mistakes and errors, therefore enabling them to practice their vocational skills and techniques.

Through the usage of virtual and augmented reality in vocational training, this technology can therefore enhance engagement of trainees by providing realistic and immersive vocational learning experiences. This includes enabling the learner to practice skills in a safe environment, allowing the apprentice to practice skills in a safe environment, whereby increasing the level of engagement (Zhang, 2022).

Chapter Four
Methodology

4.1 Introduction

The purpose of this Chapter is to present the research approach adopted to conduct an interventionist study to investigate the experiences associated when implementing extended reality technologies (XR) to train vocational apprentices to weld in the UAE. This Chapter will provide a comprehensive insight into the research paradigm, the approach, and strategy used to conduct the study while providing a critical justification. To achieve this, the Chapter will present how the interventionist paradigm was used to conduct the study through which an action research methodology was adopted to generate the active or real data, then how a qualitative strategy of conducting semi-structured interviews and focus groups was followed as a suitable means to generate the primary data. Leading on from this, the Chapter will propose a justification for the sample selection and sample size of the participants and the methods used to collect the data, including the coding strategy. Next the axiological positionality of the current study will be presented together with the importance of ensuring that the qualitative research was sufficiently robust. The Chapter will also set out how the challenges of the research project contributed new knowledge to the field of vocational welding training in the UAE. Finally, the Chapter will present the ethical considerations of the study, the limitations of the research, which then will be summarised in a chapter conclusion.

4.2 The research paradigm

Coates (2021) argued that due to the complexities of research, many doctorate students and early career researchers find it challenging to articulate then justify their paradigm. In educational research, in which this study is partly grounded, the term paradigm refers to a researcher's 'worldview' or method of thinking (Creswell, 1998). When conducting research, it is essential to consider that the data gathered and examined tends to be influenced by the researcher's worldview. Therefore, the research paradigm is a set of abstract ideas and concepts formed by the researcher's perspective and thinking. These ideas and concepts influence how the world is observed and acted upon. The research paradigm is also influenced by how the researcher assesses the methodological components of their research endeavours through a conceptual lens to choose which research methodology or methodologies should be applied and how to analyse the data that will be used. Cope (2014) contended that paradigms are a 'human construction' which addresses the underlying principles and ultimately serves as the researcher's starting point for interpreting meaning

from the data generated. In this study, the researcher used an interventionist paradigm to examine and interpret the opportunities and challenges faced by implementing the technology of extended reality in welding within a vocational training environment based in the UAE. To achieve this, the study identified that for the research to be robust and beneficial for vocational practitioners, primary data needed to be collected by investigating how welding is trained through a traditional and extended reality setting, as opposed to providing a generalised outcome through adopting a realist perspective or simply creating a new critical insight with a social constructivist approach, therefore an interventionist paradigm was selected. Having identified the most suitable paradigm, the research strategy used was inductive, which enabled the study to provide a rich, comprehensive, and holistic understanding of the themes and findings generated from the real and active data (Robson & McCartan, 2017).

4.3 Positivist paradigm

Before proceeding it is necessary to provide a context and a rationale as to why this study is a subjective project, by presenting the opposing paradigm, positivism. As a research method or approach, positivism is seen as being closely associated with a quantitative strategy and having its origins in natural sciences. As a research strategy, positivism often reduces all phenomena to verify or disprove an assumption known as a hypothesis (Guba & Lincoln, 1994). Therefore, positivism has an objectivist viewpoint on social reality, with the data collected in a numerical format by conducting a deductive strategy where the data is gathered to understand the relationship between existing knowledge and theory.

For writers such as Blumer (1956), positivism often misses or neglects the process of interpreting what is occurring in a human environment, like in a training or learning setting, which is important to this study, as the focus is on the experiences associated with how welding can be learnt using a traditional mode of education, and then by using XR technology. This lack of interpretation for Blumer (1956) means that the positivist approach brings into question whether the study is sufficiently reliable or dependable to research the experiences and perceptions of the learners and the trainers. Schutz (1962) later agreed with Blumer (1956), who highlighted that a quantitative or positivist strategy, due to its scientific focus, can omit, neglect, or even fail to accurately represent how the individual interacts with the real or the social world. The basis of Schutz's (1962) assumption is centred on the focus of a positivist strategy wanting to disprove or prove a hypothesis which is based on existing or a priori knowledge, and not to generate the richness of the experiences of the learner and

trainers as to how to gain the necessary welding skills of using XR technology in a traditional learning setting.

This perspective of Schutz (1962) was also supported by Guba and Lincoln (1994), who stated that positivism can only generate findings that exist independently and is often based on proving or disproving existing literature, which is dependent on developing a predetermined theoretical framework. This framework, however, can be restrictive as it does not enable the researcher to study real-world themes, for example, the experiences and perceptions of those learning through using welding via traditional means or through XR technology. Guba and Lincoln (1998) also highlighted that the positivist approach is often detached as the axiology seeks to be value-free. Therefore, the participant being researched is often removed from their social world, which is problematic when studying the individual's experiences and perceptions (Bryman, 2016).

4.4 The interventionist paradigm

Being an interventionist study, this section will now present the background and rationale for adopting this approach. Vitus (2017) argues that the development of the interventionist paradigm was primarily influenced by the need to develop alternative research approaches to positivism and to facilitate bridging the gap between practice and academic theory. Based on this contention that an interventionism paradigm is still a relatively new approach in research, Rescorla (2018) reported that the paradigm is still undergoing changes and modifications. Nevertheless, the most important feature that can be used to distinguish interventionism research from other research paradigms is the assumption that the researcher is the leading actor within an organisational context. However, while the researcher is the lead actor, for Lukka and Vinnari (2017) the knowledge creation process used by an interventionist paradigm tends to be achieved through social interaction. Rescorla (2018) contends that the interventionist paradigm allows the researcher to influence the nature of research by creating essential contact or change points from which the participants and the researcher can influence the research project and generate real or active data, therefore creating new knowledge and change. Reflecting this, the study adopted an interventionist paradigm using an inductive research strategy, by selecting action research as the main methodology to generate the data, from which a series of semi-structured and focus group interviews were conducted to gain a critical insight into the perceptions, experiences and behavioural changes of learners and instructors using XR technology in a traditional welding setting. This active research interaction meant that this study intended to find out the subjective as opposed to the objective meaning of social action through the interpretation of the experiences, perceptions

and behavioural changes of the learners while gaining the necessary welding skills and then also interpreting the instructor's experiences while training welding apprentices.

4.5 Rationale for choosing an interventionist paradigm

The rationale for using an interventionist paradigm in the research was based, firstly, on the relatively small sample size of the learners and trainers who would be involved in the research, therefore, it was not feasible to conduct a quantitative study and generate a generalized outcome. The second consideration was given to conducting a conventional qualitative study. To have only conducted a qualitative study on the experiences and perceptions of the learners and trainers was considered too theoretical and missed the opportunity to generate tangible outcomes and capture the experiences as the learning progressed. To ensure that this opportunity was captured, an action research methodology or approach was adopted, which enabled the researcher to interview the learners and apprentices during each stage of their learning experience and to be able to modify or intervene on the next stage of the learning process. Finally, the decision was also informed by drawing on existing studies, as presented in Chapter Three, the conceptual literature review, where there is evidence to suggest that this approach and strategy has been relatively unexplored and investigated.

4.6 Research Philosophy

In defining research philosophy, Robson and McCartan (2017) stated that the concept is a system of assumptions and ideas about the generation of knowledge that is associated with given research activity. As a concept, research philosophy provides a means to assist the researcher in conducting an inquiry with the assistance of material obtained through following a particular research approach. Holden (2004) indicated that regardless of whether a researcher is aware of the philosophical prerequisites, the study must make several assumptions before beginning the investigation. These assumptions are often linked to how the individual learns, what is their reality or ontological perspective, how knowledge is gained, the epistemological perspective of the study, and the values or axiology of the researcher. Therefore, careful consideration and thought need to be given to selecting the most suitable credible research paradigm to gain the data. The following section will present these three concepts commencing with the epistemology of the study.

4.6.1 Epistemology

In understanding the concept of a paradigm, it is necessary to set out the positionality of the research, including the epistemology ontology and axiology of the study. Epistemology for

Caldwell (2015) refers to the science of knowing; more specifically, the concept relates to the science of discovering truth or reality, as opposed to just knowing. In epistemology, there are various categories of knowledge and principles, which includes the nature of how knowledge is gained. The epistemology of a research approach emphasizes human knowledge and sets out how the researcher can gain an understanding of the subject being studied. Holden and Lynch (2004) have stated that an empirical epistemology is more likely to be accepted if the study emphasizes the significance of direct sensory experience while ensuring that the research is sufficiently robust. Therefore, it is vital to understand epistemology since it may be used to determine whether the knowledge gained by the researcher is adequately generated and informed by existing understanding or through the findings of the study. For Easterby-Smith et al. (2015), the knowledge or factual information which is generated from observable occurrences from which assumptions or conclusions can be drawn are the only acceptable forms of knowledge. This study, being an interventionist research project, using an interpretivist approach to understand the findings, therefore means that the knowledge gained was based on subjective assumptions based on interviewing participants. Therefore, the data and knowledge generated were based on subjective personal perceptions instead of providing a generalized outcome grounded in existing or known knowledge (Robson & McCartan, 2017). Through the existing literature, extended reality technologies have the potential to improve the quality of technical education in the UAE, and this research, therefore, intended to investigate the actual experiences when these technologies were applied in a vocational training setting. To achieve this, this study followed a subjective epistemology strategy to gain the required knowledge and understanding of both the learner and trainers when using XR technology to train welding techniques.

4.6.2 Ontology

The ontology of the researcher, for Liu (2016) is primarily concerned with the reality and assumptions that the individual believes and how sense is made as to the phenomena under investigation. Quinlan et al. (2019) contended that it is necessary to critically evaluate one's beliefs regarding the nature of existence and reality. Crotty (1998) argued that ontology is directly related to the nature of 'what exists'. Therefore, as a concept ontology is based on and concerned with 'how you choose to define what is real' (Hatch & Cunliffe, 2006). Consequently, the ontological positioning of research is focused on social reality, which is often reduced into two opposing categories or paradigms, as presented above: positivism and constructivism or objectivism versus subjectivism. As indicated previously, a positivist sees reality or knowledge as objective and measured, therefore seeking an independent external

reality. Opposite to this reality of a positivist is the subjective reality, which is subjective in nature. The subjective ontological position believes that ‘something exists only when you experience it and give it meaning’ (Hatch & Cunliffe, 2006). For this study, the focus was based on wanting to seek an understanding, experience, and perceptions of those who have used XR and traditional training techniques to learn how to weld. Reflecting this, the study wanted to seek the learners’ and instructors’ views, therefore, the ontological positionality of the study was to seek a subjective understanding.

4.6.3 Axiology

Aligned with the ontology and epistemological position of a researcher's viewpoint, axiology is centred on the role of values in conducting a research project. The axiology is linked closely and informed by the epistemology of the study as to how the researcher understands how to conduct the research project. In this study, the axiology of this research project was grounded in a subjective perspective where the perceptions of the learner's and trainers' experiences are captured and then accurately reported and presented. There is also an acknowledgement that the research will have a subjective bias, but will be limited so that the study provides an authentic, dependable and trustworthy account of the participants experiences.

4.7 Methodological approach

Braun and Clarke (2012) contended that the term ‘methodology’ refers to a wide range of issues, including the design of a study, methods, approaches, and procedures used to investigate the theme of the study, with the goal of discovering something new. The term methodology involves a wide variety of approaches and strategies, including data collection and data analysis techniques. Therefore, the methodology is a sequence of logical stages or steps followed which the research project adheres too, to gather and then analyse the data. All the project’s assumptions and limitations, together with the strategies used, will be presented below and justified. This will include the study’s method used to gather the data, which will include a rationale and justification of the approach. In presenting the methodology of the intended research project, it is necessary to understand the fundamentals of research. To understand the possible research strategies available, writers including Silverman (1993), Bryman (2012) and Veal (2017) identified that there are two principal research paradigms: positivism and constructivism, which were presented earlier, even though an interventionist paradigm or perspective was adopted to collect the data.

4.8 Research Design

Designing the research involves selecting the most suitable method and then deciding on an operational framework suitable for conducting the research. The research design adopted was used to bring about real change, including as to how welding is trained in an UAE vocational setting, therefore an interventionist strategy was needed, as opposed to simply prove or falsify an existing hypothesis or generate a new theory, which tend to be cross-sectional in nature. Through adopting an interventionist strategy, the study conducted a longitudinal approach to make three distinct incremental changes, then documented the outcomes and implications as the research progressed. To capture behavioural, and training changes, the study adopted a series of social constructivist strategies including using focus groups, one-to-one-interviews and analysing the personal reflections of the learners and instructors from their personal journals. Through adopting this interventionist research design, the study was able to research the changes to the learning experiences when using XR technology in welding training in the UAE, whereby enabling the study's aim and objectives to be addressed (Kan & Gero, 2017).

4.9 Research strategy

By following an interventionist study, action research is both an iterative and a recursive research approach (Lawson et al., 2015), which lends itself to enable the researcher to deliberate and create meaningful interactions with the participants involved and generate new knowledge and change during each process cycle. Unlike a positivist study which often relies on experimental design were the project process are often conducted in an objective and controlled manner so that precision is maximized, and specific conclusions can be drawn regarding a hypothesis statement (Bryman, 2012), this study was instead based on generating real change or active data outcomes. By adopting an action research strategy, as opposed to a traditional research approach, this permitted the study to generate real active data and then capture the experiences and perceptions as the research project progressed instead of undertaking the study during a discrete moment in time. Therefore, the research design was longitudinal, which meant the research was generated over time, as opposed to being cross-sectional. Being longitudinal, the strategy can enable the capture of a more profound reflective knowledge, which can then be used to build up and then re-introduced to the participants, where the outcomes can be planned for, and the changes or *action* to be taken, if needed (Coates, 2021). Therefore, action research seeks to investigate transformative change through simultaneous processes informed by conducting the research, which have been informed by iterative critical reflection. In Figure 4.1, the processes followed when

conducting the study are shown below, which commenced with a pilot interview, which will be critically discussed in the next section. From the outcome of the pilot study, the main study's participants were selected, before the first intervention cycle commenced. All through the data collection strategy, the quality of the data was constantly reviewed. Finally, the study ensured the research protocol followed the ethical guidelines of the University, but also recognised that this participatory study had subjective limitations which needed to be reflected on. These challenges will be critically reviewed later in this Chapter.

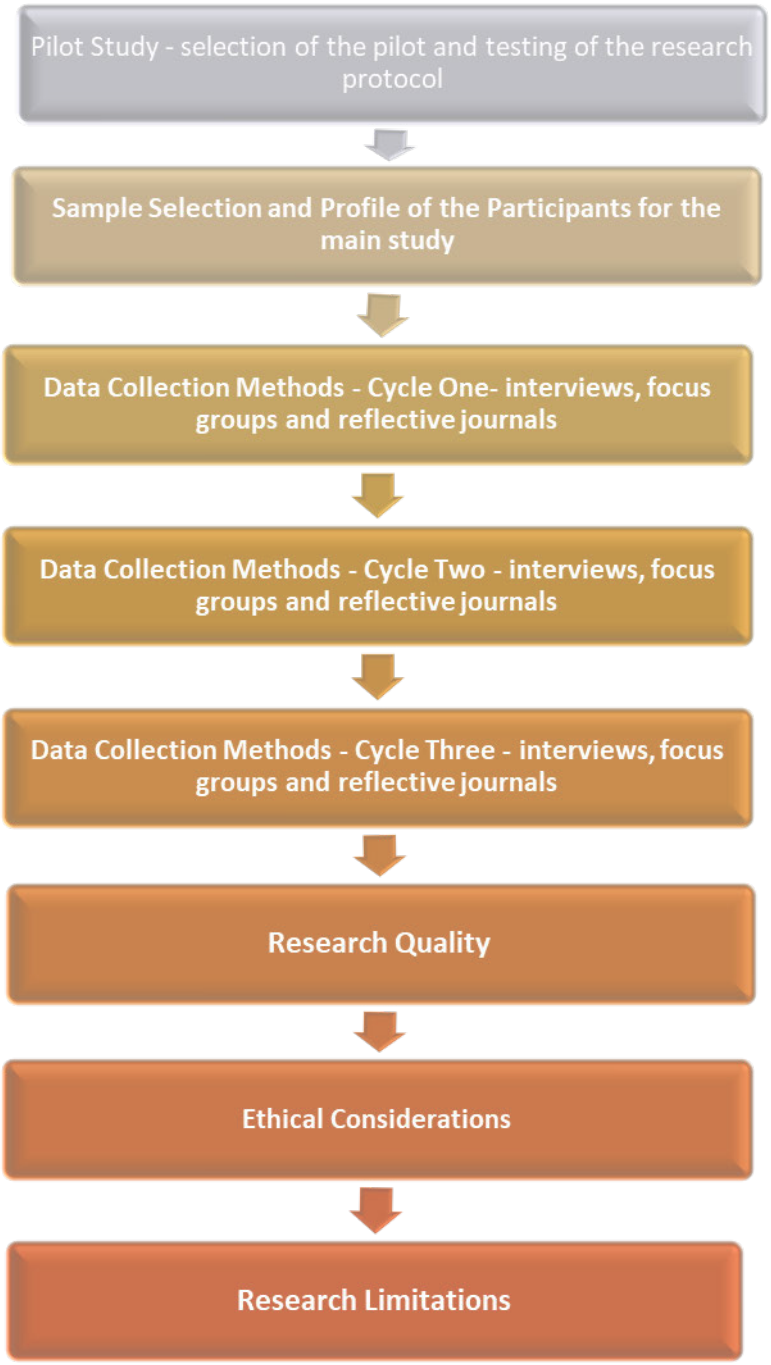

Figure 4.1 Research Strategy

The origins of action research are accredited to Kurt Lewin from the late 1940s, which was used to find solutions to social problems (Coughlan & Coghlan, 2002; Kemmis et al., 2014; Bargal, 2006). Coughlan and Coghlan (2002) defined action research as a strategy 'that is both embedded in and participatory, including a sequence of activities designed to solve a problem and occurring at the same time as the action' (p. 222). Part of the background of action research is the premise that the approach is most suitable for conducting a study when the researcher is a member of the topic or organisation which is being examined (Coughlan & Coughlan, 2007). This aspect of the researcher being actively involved was part of the rationale for using this approach. The approach was also designed to address social issues and broader educational concerns, therefore, as a technique can be used in a training and development-based research project (Thorpe & Holt, 2008). The sequence approach, as indicated by Coughlan and Coghlan (2002), means that action research, as mentioned above, is iterative, with each step or phase informing or influencing the outcome of the next phase or step, as the progress to date is re-assessed or re-evaluated based on the previous results (Robson & McCartan, 2017). Action research design therefore often consists of several cycles to gather data and implement the required changes. This will continue until the researcher reaches a point where change is no longer needed. To achieve this, each cycle was subdivided into four distinct stages: plan, act, observe, and reflect, as shown in Figure 4.2, which illustrates each stage of the design, which will be covered in more depth in section 4.12, as to how this model was applied. As in this study, each cycle informed the next stage, although the last cycle was primarily based on the findings and reflections of the previous phase

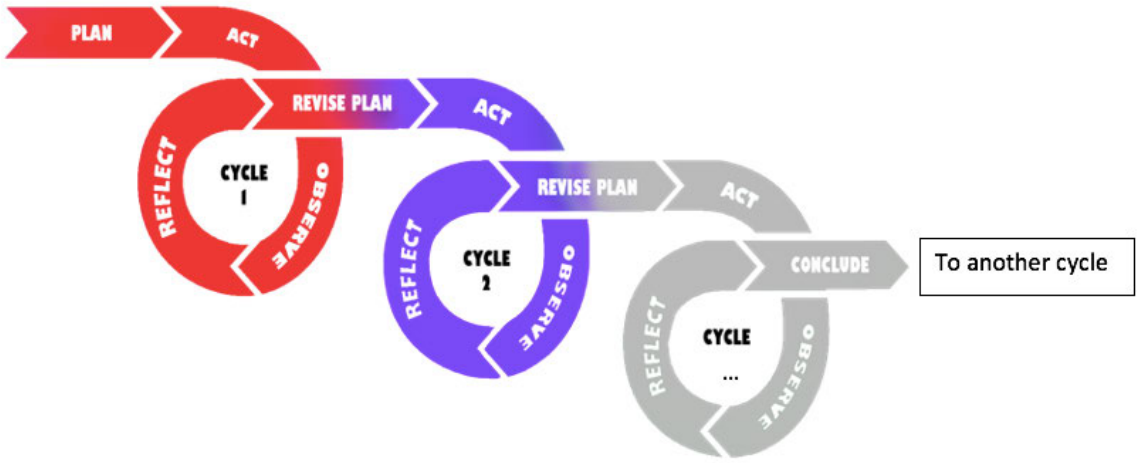

Figure 4.2 Design Cycle

A central part of action research is the simultaneous focus on 'action' and 'research' being conducted almost simultaneously. Therefore, in conducting an action research project, the researcher can seek to assess its effectiveness before making changes depending on new information that has emerged (Robson & McCartan, 2017). Therefore, as a research design, action research can be effectively used to improve or address real issues rather than proving or disproving an assumption or formulating or generating a new theory. When applied to this research project, the study was able to acquire real-time outcomes as to the challenges and benefits of implementing XR in training apprentices in welding within a UAE vocational training educational setting.

For the design to be effective, the strategy required the participants to be involved in the process of planning and then participating in the intervention process. To achieve this, the main influencers were the instructors. The instructors were asked to consider and plan for each stage of the intervention, setting out their learning objectives and strategies as to what the learning outcomes were and how they were going to be achieved. These decisions were also based on the instructor's lesson plans. As for the apprentices, these individuals were involved in the initial decision-making process as to the content being delivered and were informed as to the intended learning outcomes.

As mentioned above, the data was captured using a constructivist perspective with the study using semi-structured interviews with the instructors and focus groups for the apprentices. By using a focus group and interviews, the instructors were selected to be a group of like-minded individuals who possessed certain common or specific characteristics that enabled them to discuss a particular topic or theme, which in this study was related to training basic welding skills (Anderson, 1990). As there were two primary groups of participants, the apprentices and instructors, the groupings were kept separate, in other words, one focus group was made up of apprentices, and the instructor group were interviewed on a one-to-one basis. The purpose of the focus groups and the individual interviews was to provide an in-depth investigation into how XR technology was experienced in a welding training setting from a learner and instructor perspective. Therefore, the focus group and interviews were performed at the end of each training cycle. The first interview was conducted after finishing the apprentice's training in traditional welding. The second cycle was performed after the completion of the training in welding with extended reality technology, although the instructors were not formally interviewed at this stage, but their perspectives were captured after the third cycle. For the final cycle, the focused group interviews were conducted after the completion of the welding training session which involved using the combined training

methods of XR technology along with traditional welding equipment. The focus group and interviews were audio recorded together with the researcher taking notes as to emerging themes and reflections. These notes were reviewed to ensure that no observation, opinion or idea was left out when the data was being analysed.

4.10 Pilot study

Before conducting the main research project, a pilot study was conducted. There were several significant questions which emerged prior to undertaking the research project, which including: what if the interview questions were unclear to the participants? What if the interview questions were not suitable to achieve the research objectives? Therefore, to address these questions it was essential to conduct a pilot study to be able to address any issues prior to the main study, and to ensure that the study protocol was effective and appropriate. Paisley and Reeves (2001) stated that in qualitative research, the researcher is the primary tool in data generation, and interview questions are at the core of interview. Furthermore, an in-person interview is widely recognised as a proper method for a qualitative investigation to pursue the understanding of those who have experienced or are experiencing the phenomenon (Collingridge & Gantt, 2008), therefore, it is essential to pilot the interviews to test the questions and to gain some practice in interviewing.

The pilot study took place in January 2021 at the technical training school in the UAE, which involved five male participants, which comprised of three learners and two instructors. The criteria for the participants for the pilot interview was based on having immediate access to them, therefore, they were learners and colleagues known to the researcher at the technical training school. However, these participants were also selected to ensure that they had a background in welding training, and the criteria used for the pilot study ensured that the participants still met those of the main study. The participants selected for the pilot study were being trained in the basic techniques associated with welding, which mirrored the theme of the main study.

The pilot interviews for both the learners and the instructors were focused on the themes as presented in Table 4.1, which included for the learner: ‘When you first started to learn how to weld, what was your initial experiences?’, ‘Do you think it was easy to perform the required tasks during the training with the XR simulator?’, ‘If you were initially wary of the welding environment, what could be changed?’, ‘What prevented you to learn how to weld?’ Then for the instructor, the following was asked: ‘What challenges did you face as a subject trainer in

welding?' and 'what was the benefits of teaching welding when using XR compared to the traditional mode of learning?'

Participant profile	Research Objective	Interview question	Outcome
Learner	**RO1**: To critically analyse and evaluate associated challenges and opportunities of implementing AR/VR technologies in vocational education in the UAE.	What were the benefits gained from the training with XR technology welding simulators?	The learners found that the questions were clear and straightforward to answer. The findings indicated that the learners had completed a particular task and were able to provide an insightful account of their experiences indicating they understood the question, and the interview data addressed the research objective. The learners were able to also when prompted to reflect on their earlier learning experience using the traditional welding equipment to compare this with using XR technology. This confirmed that the opening question was suitable: *What are the challenges and opportunities of training welding using conventional welding equipment in a vocational educational setting in the UAE*? Other questions included: *What were the challenges faced in the training environment when being trained using traditional welding equipment*? *What are your experiences when training using the traditional equipment and environment?*
Learner	**RO1**: To critically analyse and evaluate associated challenges and opportunities of implementing AR/VR technologies in vocational education in the UAE.	What are the challenges and opportunities of implementing extended realities technologies in a vocational education setting in the UAE?	The learners were able to understand the questions and provide informative examples of both the challenges and opportunities associated with XR technology, but missing was the need to ask about the challenges linked to the learning environment. This led to the development of a follow-up question:

			What were the challenges faced in the training environment when being trained using traditional welding equipment and then using XR technology?
Learner	**RO2**: To critically evaluate the student's learning experience when implementing augmented reality and virtual reality technology in vocational education in the UAE.	What were the experiences of using XR technology in assisting how to learn to weld?	Again, the learners were able to clearly understand the questions. The learners were able to clearly articulate their experiences and perceived benefits of using XR based welding training. Opening question, this confirm the following question: *how did the learning experience change when implementing extended realities technology in vocational education in the UAE?* Then followed by: *What was the expected learning experience when using extended realities technology in a vocational education in the UAE when learning how to weld?* *What were the positive and negative experiences of using XR technology*? *What were experiences as to using XR technology to train the apprentice to weld*? *What were the challenges and benefits of training using XR technology*? Missing however, was the need to ask the learner to reflect more deeply on their experiences, this led to the initial research question to have follow up question: *Reflecting on your experiences of using XR, how did this technology assist you?* Then an additional follow-up question was added:

			What were the positive and negative experiences of using XR technology? *What was their experience of implementing extended realities technology in vocational education in the UAE to train welding*?
Instructor	**RO3:** To critically evaluate the instructor training experience when implementing augmented reality and virtual reality technology in vocational education in the UAE. .	1. Were there any challenges faced as a trainer of vocational welding ? 2. Were there any benefits of teaching welding with XR technology?	The instructor could answer the questions without any further clarification. However, the initial question was not appropriate as it did not provide any depth, it was presented as closed question. The question was changed to: *What was the experience of implementing extended reality technology in vocational education in UAE to train welding*? Then the follow up questions were added: *What were the benefits of training welding using XR technology*? *What ere the limitations of training welding using XR technology*?
Instructor	**RO4**: To give a recommendation on overcoming the challenges faced in exploiting the opportunities of AR/VR technologies in vocational education in the UAE.	What was the best training method or approach you followed to train welding?	The instructors understood the questions asked. The instructors could accurately explain the challenges of teaching welding and how XR had and could potentially be used in the future, therefore the question did not change: *What was the experience of implementing extended reality technology in vocational education in UAE to train welding*?

Table 4-1 Pilot interview protocol

The pilot interviews were conducted to help understand any problems during the data collection phase and improve the interview questions or the interview design. The data and experience obtained during the pilot interviews helped to modify the research protocol. The study also offered the researcher practical insights about the order in which the questions needed to be asked to generate maximum engagement from the participants.

During the pilot interviews, two out of the three participants, two apprentices and one instructor, regularly referred to the benefits of adopting extended reality. For these participants, particularly the apprentices, they tended to move the discussion from the main topic of the XR technology as a training methodology to talk about artificial intelligence and other topics that were not related to the research. The outcome of the pilot interview indicated that in the main, the questions were suitable, but when the main study was conducted, the researcher needed to ensure that the learners were focused on recalling their learning experiences, as opposed to other unrelated themes, such as artificial intelligence.

For the instructors, the pilot study was insightful, but was also a forum in which they could express their frustration of needing to stop and start the training sessions when using the traditional welding equipment and the pressure associated with training a group on an individual basis. This issue of stopping and starting became a key theme of this study as to the challenges associated with traditional welding. The format of a focus group for the learners proved to be suitable as it enabled the whole group to share their experiences together, while for the instructors, the one-to-one format enabled them to talk freely about their challenges they faced on teaching welding using a traditional format.

4.11 Sample Selection and Profile of the Participants

Prior to the actual data collection process, it was essential to identify the most appropriate sampling criterion that would be used for recruiting the participants. In line with Stratton (2021), Etikan, Musa and Alkassim (2016), Else-Quest and Hyde (2016) and Setia (2016) it is an important consideration which should be made when designing the sampling criteria. Consideration was given as to whether the study should adopt a quasi-experimental design, which can include systematic, stratified, matched random, quota or convenience sampling strategy. This study adopted a convenience sampling approach to recruit the participants, as it was dependent on access to the course, the instructors and apprentices who were learning how to weld (Else-Quest & Hyde, 2016; Setia, 2016).

For the main study, 12 male apprentices from a government entity in the United Arab Emirates were chosen. These apprentices were selected and nominated by the government entity after meeting certain requirements to attend a welding foundation course at a technical

training school in the United Arab Emirates. The apprentices ages ranged from 21 to 58 years old. It should be noted that there were no restrictions or age limit to enter any technical training course provided the apprentices could physically perform the training tasks. The recruited apprentices were already working for the UAE government entity, and had enrolled on the welding foundation course as the entity encouraged cross training for its employees in order to increase their knowledge and technical skills, which is linked to the strategy of ensuring that vacancies or shortage of welders is met. Therefore, the technical experience of this sample ranged from 0 to 4 years.

The research project also recruited and interviewed 6 TVET welding instructors from the technical training school. The recruited instructors were aged 36 to 58 and had teaching experiences ranging from 9 to 11 years in training welders. The profile of the participants is shown below in Table 4.2 and Table 4.3.

Participant ID	Role	Level of experience	Age
1	Apprentice	4	58
2	Apprentice	2	32
3	Apprentice	0	47
4	Apprentice	3	53
5	Apprentice	0	44
6	Apprentice	0	47
7	Apprentice	0	32
8	Apprentice	0	22
9	Apprentice	0	30
10	Apprentice	0	30
11	Apprentice	2	25
12	Apprentice	0	24

Table 4-2 The Learner Participants

Below are the instructor's profile including their years of instruction.

Instructor ID	Role	Years of teaching	Age
1	Welding Instructor	10	44
2	Welding Instructor	11	50
3	Welding Instructor	10	39
4	Welding Instructor	10	34
5	Welding Instructor	9	36
6	Welding Instructor	11	58

Table 4-3 The Instructor Participants

4.12 Data Collection Methods

The main study involved conducting a three-cycle process to gather the data. To achieve this, each cycle was subdivided into four distinct stages: plan, act, observe, and reflect, as shown in Figure 4.3, which illustrates each stage of the design. Each cycle informed the next stage, although the last cycle was primarily based on the findings and reflections of the previous two phases.

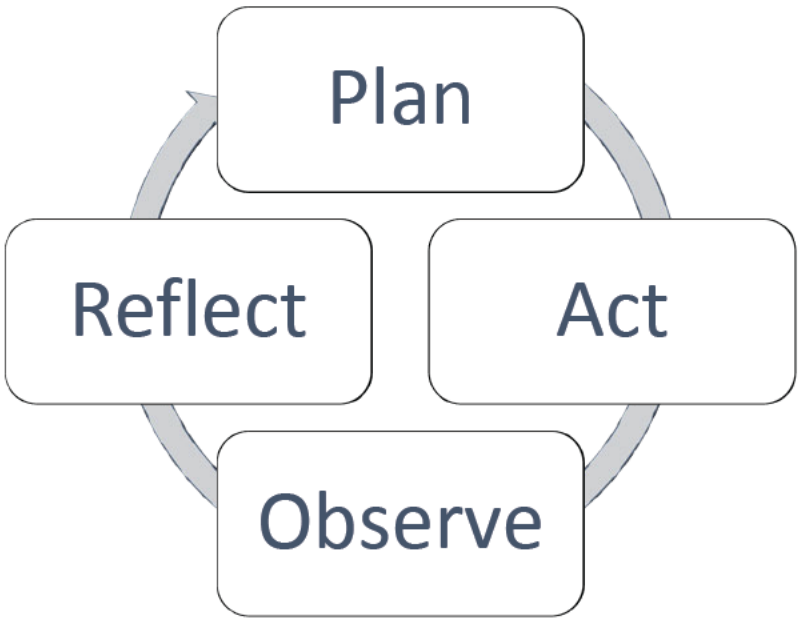

Figure 4.3 the single action research stage (Hopkins, 1993)

The first cycle involved the apprentices in the nominated welding course completing a practical project to demonstrate their knowledge and abilities in performing a fundamental welding task. The task involved welding a T-shaped coupon. For most of these learners, it was the first time they had performed this task and experience working in a welding workshop.

4.12.1 First Phase

The first phase commenced with the apprentices being shown and taught entirely using only traditional welding equipment. Before the first cycle of instruction and training commenced, both the apprentices and the instructors were asked as to their initial expectations, pre-conceptions, and what they expected the activity and environment to be like. Then after the training session was completed, the learners and instructors were then asked about their actual experiences and then to reflect on what had been learnt before self-assessing their level of proficiency or competency. At the same time, the instructors were asked to document their experiences of training the learners in the welding task in a traditional learning setting, while the **researcher observed the entire process as an outsider**. The study also required the instructor or trainer to evaluate the learners' performance in performing the task and document any challenges they faced while reflecting on the benefits of using the actual welding equipment in a life-like setting.

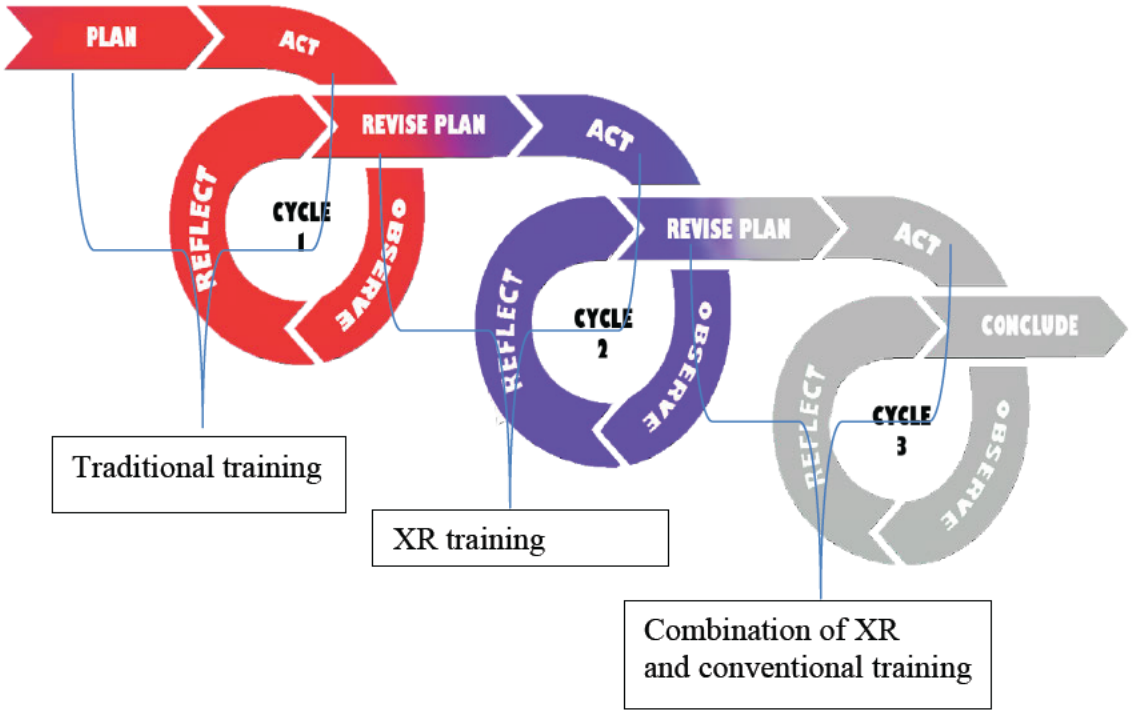

Figure 4.4 Research Design Cycle

In conducting this study, the learners' perspectives were captured in a focus group, where the individuals were asked the key question which was presented in Figure 3.1 as to *what are the challenges and opportunities of training welding using conventional welding equipment in a vocational educational setting in the UAE*? Then leading from this question, the group was asked a follow-up question: *what were the challenges faced in the training environment when being trained using traditional welding equipment*?

For the instructors, the semi-structured interviews, the following question was devised based on Figure 3.1 in Chapter Three: *what were their experiences when training using the traditional equipment and environment*? There was a follow up question: *as what were the challenges and benefits of training with the actual welding equipment*? Then after conducting the interviews with the learners and instructors, which included capturing the overall reflective experiences of phase one, the researcher implemented the second cycle with the learners.

4.12.2 Phase Two

The second cycle, which was based on the same learning objectives and outcomes consisted solely of training the apprentices through the usage of an extended reality simulator. The task conducted was of the same level of proficiency as the first cycle. Before the commencement of the second phase the trainees were asked as to their expectations and pre-conceptions of using this technology. The learners were asked in the focus group: *what was the expected learning experience when using extended realities technology in a vocational education in the UAE when learning how to weld?*, which was adapted from Figure 3.1 in Chapter Three. The learners were also asked to reflect on their experiences of XR, by being asked: *reflecting on your experiences of using XR, how did this technology assist you*? Finally, there was a follow-up question: *what were the positive and negative experiences of using XR technology*?

For the instructors, in the semi-structured interviews, they were asked during cycle three, what were their *experiences as to using XR technology to train the apprentice to weld*?, informed by Figure 3.1, Chapter Three. Then a follow-up question: *as to what were the challenges and benefits of training using XR technology*?

At the end of the second phase, the learners were asked to reflect and then evaluate their experiences. This reflection included also comparing the practical exercise using real welding equipment compared to the XR technology. The study also involved observing the training

and the performance of the apprentices during their time using the XR welding simulators to evaluate, as an outsider, of both the learners and the instructions' experiences. The data for the pre- and post-phase was collected using the same focus group as conducted in the first phase, which gathered both the personal and group experiences. It should be noted that during the second cycle, the interviews did not involve the instructors from a formal perspective, due to their availability as the workshop environment needed to be re-configured for the final cycle, the hybrid approach. The study did however capture the experiences of the instructors for the second and third cycle during the final series of one-to-one semi-structured interviews.

4.12.3 Phase three

To determine the most optimum or ideal format to train apprentices as to how to learn to weld, and address the research questions as set out previously, the third cycle consisted of a combination of training utilising an extended reality welding simulator and using conventional welding equipment. The research again followed the same strategy to collect the data as the previous two cycles, with the researcher observing the third cycle as an independent outsider. The learners were asked based on Figure 3.1, Chapter Three: *what was their experience of implementing extended realities technology in vocational education in the UAE to train welding*? To follow up, the apprentice cohort was asked: *what were the benefits of training welding using XR technology*?, then what *were the limitations of training welding using XR technology*?

For the instructors, the one-to-one interviews also asked the same questions but from a tutor's perspective, based on Figure 3.1, Chapter Three: *what was the experience of implementing extended reality technology in vocational education in UAE to train welding*. The follow up questions were: *as an instructor what were the benefits of training welding using XR technology*?, then *what were the limitations of training welding using XR technology*?

At the end of the third cycle, and based on the interview results generated, no new changes or recommendations were identified for further improvement as to the quality of the welding training experience, as the primary research stage reached saturation.

4.13 Research Quality

This section will outline how quality was achieved when conducting an interventionist study through using a qualitative research strategy of conducting semi-structured interviews and focus groups. In doing this, the section will set out how quality and robustness of the study was achieved. Key writers in the field of quality qualitative research, include Guba and Lincoln (1985), Guba (1981), Lincoln (1995), Lincoln and Guba (1985), Lincoln et al.

(2011), who contend that there are five pivotal concepts widely used to evaluate the quality of qualitative research: credibility, transferability, dependability, confirmability, and authenticity. These five characteristics are different to a positivist study, as positivism sees research robustness needing to be valid and reliable. Reflecting this use of terminology to be aligned to a qualitative study, the terms validity and reliability will not be directly used.

Furthermore, for Lincoln and Guba (1985), in qualitative data, the researcher needs to ensure that the findings are robust, dependable, authentic, and trustworthy in gathering, coding, and presenting the data. These characteristics are essential, as consistency and legitimacy issues are often cited as reasons why qualitative research is seen as less trustworthy than a positivist study (Shenton, 2004). To ensure that a qualitative study addresses these concerns, which are often raised by positivists as to the weaknesses of constructivist studies, Lincoln and Guba (1985) indicated that there is a need to assess the trustworthiness of qualitative research criteria as to the legitimacy, dependability, rigour, and authenticity of the process followed to give the reader the confidence as to the robustness of the findings. Therefore, this research project went through prolonged engagement with the data and constant observation by the researcher to increase and enhance the credibility of this qualitative research project.

Lincoln and Guba (1985) highlighted the importance of research dependability or reliability as an overarching question and concern for all research projects to carefully consider. Dependability includes how and whether the data generation techniques and analytical procedures used have produced or generated consistent and robust outcomes. For qualitative studies that use interviews including focus groups and semi-structured interviews, reliability, which is a quantitative term, is changed to become dependable. To ensure that this study was dependable, the project ensured that the data collection strategy enabled the participants to freely talk and express their opinions as to their learning experiences while learning to weld. This included ensuring that in the focus group environment, all participants had an opportunity to express their perspectives and experiences. To reinforce this, the interviews were also conducted in Arabic so that the apprentices were able to express their views without any language barrier. The dependability was also assured as the interview data were coded in Arabic so that the true meaning was maintained before finally being translated. Finally, the coding process was constantly reviewed to ensure that all the data was analysed, and all themes were identified, which is the next section of this Chapter.

4.13.1 Data analysis strategy

To conduct this data analysis and ensure that the study was dependable, Gioia et al. (2012) recommended that data analysis can be conducted via following a three-stage approach. For Gioia et al. (2012), the **first phase** was centred on ensuring that the data integrity and authenticity of the meaning of the findings was preserved. The **second phase** was based on ensuring that the information has intellectual or theory-centric integrity and finally **thirdly**, the conceived coding framework, the terms, themes, and other aspects are turned into a data structure for assessment. Based on these three phases, the data process can assist the researcher to identify emerging themes. In contrast, Ollerenshaw and Creswell (2002) outlined a five-step analytical procedure which commences with the need for accurate transcription from the recorded data. The second phase entails extensive reading of the transcripts so that thematic patterns can be identified. Ollerenshaw and Creswell (2002) recommended using NVivo or Nudist software, to colour code and group patterns that are visually similar. The last stage of Ollerenshaw and Creswell (2002) approach involves sequencing the colour codes. In line with Ollerenshaw and Creswell's (2002) concept, the data analysis in this research project followed a thematic approach as proposed by Braun and Clarke (2006),

The outcome of the interviews was organised into a hierarchical structure that included main, sub, and sub-ordinate themes. This hierarchical approach helped to categorised the data in a systematic form. The breakdown of these different levels in this study's hierarchical process were as follows:

1. The primary themes that represented the overarching ideas or concepts that emerged from the data, captured the main patterns or topics observed during the analysis. This grouping provided a broad overview of the main findings generated from the data.

2. The sub-theme 1 or superordinate represented the more specific categories which emerged from the main themes. These sub-themes captured the different insights related to the main theme but provided a more detailed insight into the data.

3. Sub theme 2 or ordinate themes, was even more focused, which was linked under sub-themes 1. Sub-theme 2 captured the finer nuances or variations within the existing theme or sub-theme. Subordinate themes helped to further break down the data to provide a deeper level of analysis.

4. Sub theme 3 or the sub-ordinate level, was more detailed than subordinate themes 2, which further broke down the data providing a deeper understanding.

5. Sub theme 4 or sub-sub-ordinate level, further reduced the theme to provide a final focus on the outcomes of the interview data.

There were several advantages in using a hierarchical approach. This included assisting in obtaining clarity, providing flexibility for the researcher to refine, modify or even to add any emerging themes or concepts if and when needed. The approach further assisted in uncovering patterns, relationships, and insights within the data, leading to a more robust and meaningful interpretation which will be presented below in the first, second, and the third cycle coding outcomes.

4.13.2 The Rationale for starting with Traditional training as the first cycle

The first step in conducting the action research project was to identify and define the focus of the investigation (Christ, 2018). In this research project, there were identified issues and challenges associated with training apprentices to weld using traditional methodologies. Therefore, the decision was made to start the first action research cycle with the existing training methodology of using traditional welding equipment. This strategy enabled the capturing of the apprentices' experiences and those of the instructors from the existing learning approach. The first phase was then used to inform the next stage as to the potential usage new XR technologies being used to overcome the identified barriers when using traditional welding resources. Starting with the traditional training techniques also provided a baseline for evaluating the current training approach and identifying any deficiencies or areas for improvement, together with the means to compare and contrast the two different methodologies.

4.13.2.1.1 First Cycle Coding Outcome

The first phase involved the gathering, recording and then transcription of the data. From the first phase the following themes emerged, which included that the environment was unfamiliar for the apprentice, that the sparks, gas, heat, and the noise was off-putting, as can be seen below in Table 4.4. The findings also reveal there were gaps in the apprentices' learning, which were compounded by the distractions of the welding workshop, together with being impeded by the need to wear the PPE. However, there were benefits, such as handling the real equipment and experiencing the actual environment. From the findings for the learners, the data was coded using the following nodes, as shown below in Table 4.4. Table 4.4 shows the superordinate or primary theme, such as overall benefits, and then the ordinate, and related sub-ordinate themes.

Primary theme	Sub-theme 1 Superordinate	Sub-theme 2 Ordinate	Sub-theme 3 Sub-ordinate	Sub-theme 4 Sub-sub-ordinate
Conventional learning to weld	**Overall benefits**			
Overall Benefits	***Equipment***	Equipment	Equipment – welding gun, materials, and PPE	Materials
				PPE
	Skills	Skills	Essential skills	Skills – eye and hand coordination
	Environment	Skills	Awareness	Safety and security
Overall limitations	***Equipment***	Equipment	Equipment – welding gun, PPE, materials	Weight of the equipment
	Environment	Equipment	Distractions	Poor ventilation
				The noise, smell and sparks
	Skills	Skills	Essential skills	Skills – eye and hand coordination not achieved due to poor vision
	Practice	Skills	Stopped training	The need to wait
				Inability to practice

Table 4-4 Learner's Cycle One data coding tree

The first cycle also captured the experiences and perspectives of the instructor, which was also coded, and found that the conventional environment exposed the apprentice to the equipment and the challenges associated with welding, including an awareness and respect of safety issues. The study also found that the instructor needed to replenish the materials needed, recalibrate the equipment and often conduct the training on a one-to-one basis, therefore not enabling the learner to practice, as shown below in Table 4.5. Again, in Table 4.5, the superordinate, ordinate and sub-ordinate themes are presented.

Primary theme	Sub-theme 1 Superordinate	Sub-theme 2 Ordinate	Sub-theme 3 Sub-theme	Sub-theme 4 Sub-sub-theme
Conventional learning to weld				
Overall Benefits	***Equipment***	Equipment	Welding gun, PPE, materials	Provide the real experience with the PPE
				Practice on real materials
				Handle the actual equipment
	Environment	Skills	Distractions	Provided an authentic environment
	Essential skills	Perception of the task	Authenticity	Learning to use the actual resources and re-calibration
				Safety issues and awareness
Overall limitations	***Equipment – welding gun, PPE, materials***	Perception of the task	Restrictions	PPE can be restrictive
				Resources are heavy
				Need to replenish materials
	Environment	Perception of the task	Time	Delays due to one-to-one basis
		Environment	Heat	Humid environment
				The noise of the workshop

Table 4-5 Instructor's Cycle One data coding tree

4.13.2.2 Second Cycle Coding Outcome

In the second cycle the focus was on the usage of the XR technology to train the apprentices to weld. The learners identified the benefits as being free of any distractions such as the sparks, able to practice and re-practice their newly acquired skills, the ease of communication and to understand the instructor's guidance more easily. There was also the benefit of gaining the fundamental skills which enabled the learner to acquire basic psychomotor skills which proved to be a motivational tool in changing their behaviour or attitudes towards learning, see Table 4.6. However, the focus group also reported that the XR headwear was heavy, and that the equipment was unable to accurately represent the real welding environment. For the instructors, although the data was generated from the third cycle, there were a series of benefits and limitations associated with the usage of XR technology, including the need for no physical materials needing to be prepared prior or during the lesson, therefore giving them more time to assist the learner. There was also the ability for the instructor to monitor and assist the entire cohort, while also getting real-time information as to the learner's progress. There were however issues as to the learner's becoming over-confident and that the safety issues were not being accurately reproduced and that the equipment was not a true reflection of the actual resources (see Table 4.7).

Primary theme	Sub-theme 1 Superordinate	Sub-theme 2 Ordinate	Sub-theme 3 Sub-ordinate	Sub-theme 4 Sub-sub-ordinate
XR technology to weld				
Overall benefits	***Environment – noise, smells, heat, sparks***	Equipment	Lack of distraction	No noise, electric and sparks
				Less humid
				The XR equipment is easier to handle
	Learning	Perception of the task	Time	More time to practice
				Instructor available
				Became competitive
				Real-time feedback
Overall limitations	***Equipment – welding gun and headwear***	Equipment	The headwear	Heavy to wear
				Not real or authentic

Table 4-6 Learner's Cycle Two data coding tree

Below are the nodes for the instructors, which was conducted during the third cycle, with the trainers drawing on their reflections and journals.

Primary theme	Sub-theme 1 Superordinate	Sub-theme 2 Ordinate	Sub-theme 3 Sub-ordinate	Sub-theme 4 Sub-sub-ordinate
XR technology to weld				
Overall benefits	***Equipment***	Equipment	Delays minimized	No need for recalibration
				No need for preparation of materials
	Learning	Perception of the task	Time	More time with the learner
				Able to monitor the progress in real time
				Able to talk / instruct the learner
Overall limitations	***Equipment***	Perception of the task and equipment	Authenticity	The equipment is not real
	Environment	Perception of the task	Authenticity	Does not recreate the safety issues

Table 4-7 Instructor's Cycle Two data coding tree, conducted during the third cycle

4.13.2.3 Third Cycle Coding Outcome

Finally, the third cycle, the findings revealed the following themes. For the learners, there was a recognition of the need to learn the fundamentals and then experience the actual environment, while for the instructors it was learning the skills of using the physical resources and being able to operate within the safety requirements.

Primary theme	Sub-theme 1 Superordinate	Sub-theme 2 Ordinate	Sub-theme 3 Sub-ordinate	Sub-theme 4 Sub-sub-ordinate
hybrid approach of XR technology and actual resources to weld				
Overall benefits	***Learning***	Perception of the task	Fundamentals with XR	Acquire the skills with XR
			Psychomotor	Acquire eye and hand coordination ability with XR
			Confidence / psychological	Become confidence in the basic techniques with XR
	Equipment	Perception of the task and equipment	Experience the real welding resources	Handle the actual resources
		Perception of the task and equipment	Familiarity	Familiar with environment
Overall limitations				
	XR	Perception of the task and equipment	Equipment – welding gun and headwear	Not real
	Conventional	Equipment	Environment	The noise levels

Table 4-8 Learner's Cycle Three data coding tree

For the instructor, the hybrid environment generated the following themes and nodes:

Primary theme	Sub-theme 1 Superordinate	Sub-theme 2 Ordinate	Sub-theme 3 Sub-ordinate	Sub-sub-theme 4
hybrid approach of XR technology and actual resources to weld				
Overall benefits	***Equipment***	Perception of the task and equipment	Using XR	Enabled one-to-one instructions in basic skills
	Learning	Perception of the task	Time for instruction	Manage the entire cohort
			Communication	Better communications
	Using the actual welding resources	Perception of the task and equipment	Use the resources	Permits the learner to handle the actual resources
			Safety and security	Familiar with environment and safety issues
Overall limitations	***XR Equipment***		Welding gun and headwear	Cannot be replicated by conventional resources can be used
	Conventional equipment		Resources	Need for resources and learn to calibrate

Table 4-9 Instructor's Cycle Three data coding tree

4.13.2.4 Validated of the Study

For the study to be valid the findings and the outcomes to be accurately measured, is often associated with quantitative studies. However, being a qualitative study, consideration was given to ensure that the research was valid and reliable, but from a subjective perspective, authenticity was seen as important whereby providing the reader with the confidence that the data generated and presented was trustworthy. From the outset of the study, the researcher recognised that a generalised assumption could not be made, as the sample size was seen as being too small. As a result, the study could only be used to inform training practice, as opposed to providing an inferred or generalised outcome.

4.13.2.5 Authenticity

Reflecting this, the validation of the outcome of the study was seen as not suitable, instead, the study focused on *authenticity*, which is closely linked as being critical to qualitative studies (Robson & McCartan, 2017). For a qualitative study to be authentic, it is necessary to consider credibility, which is associated with the believability or trustworthiness of the findings. For this study to be credible, the findings accurately represented the experience of the learners and instructors being interviewed, then, the data was interpreted so that the participant's opinions were accurately captured. This was achieved by the interviews being conducted in Arabic while enabling all participants to have a voice to express their opinions, and the coding process included a constant review of the transcripts.

4.13.2.6 Transferability

Closely linked to authenticity and credibility is *transferability*. Transferability is associated with how future researchers can access the findings and then potentially use them for future research projects. However, being qualitative, this can be problematic, as, unlike a quantitative study which can be replicated, Baxter and Eyles (1997), argued that transferability is less important for qualitative studies compared to credibility and authenticity. All research, whether it is qualitative or quantitative, needs, however, to be robust. In this study, to ensure that the research was robust, and that the data could be trusted, the researcher ensured that there was integrity in the narrative of the participants. To achieve this, the study recorded the interviews in Arabic so that during the analysis process, the data could be accurately reviewed. Furthermore, the transcripts were constantly reviewed and returned to by the researcher to check for additional new and emerging themes.

4.13.2.7 Confirmability

Finally, *confirmability* for a qualitative research project relates to the extent to which the findings represent the perspective of the participants in the study compared to those of the researcher. To address this and ensure there is confirmability, Huberman (1996) stated that honesty, authenticity and truthfulness are vitally important to make the study sufficiently robust, particularly for qualitative research, which is reliant on the accurate reporting of the participants' perspectives. To achieve this, the participants were asked to review the transcriptions, which were transcribed in Arabic, to ensure that the data was reliable and valid. As none of the participants requested to review the transcripts, the researcher instead constantly reviewed both the transcripts and the recorded interviews to ensure that the data was accurate. This process of constantly reviewing included at the transcription stage, then later during the coding of the findings follows the advice of Creswell and Miller (2000).

4.14 Ethical Considerations

Research ethics are of a vital importance for any study and has implications for how the project is conducted. Undertaking research with participants in an interview setting is always challenging for any researcher, but it is made more challenging when dealing with focus groups. The following section sets out the ethical challenges associated with the study and how these concerns were addressed. Firstly, this research project was conducted within the Principles and Procedures framework of the University of Gloucestershire, which is based on the British Educational Research Association (BERA) and the British Sociological Association (BSA).

The University guidelines set out that the researcher has many responsibilities, which include the physical, social and psychological well-being of those participating (University of Gloucestershire, 2022), which included the requirement for the participant to give freely informed consent. In this study, informed consent from the participants was given prior to the study, which included the aim of the project, the reasons for the study and the usage of the data afterwards. The participants' anonymity was assured, together with the guarantee of the confidentiality of the data. Consideration was also given to the fact that the participants were apprentices, and the researcher stressed that participation was not compulsory.

Using a focus group format, the power relationship between the participant, other participants and the researcher needed to be carefully considered. To achieve this, the participants were

informed that all other members of the group were given the same amount of time to express their opinion and that each member of the group was respected. This strategy enabled all participants to be actively involved, and no single person dominated or influenced the grouping.

All participants, whether in the focus group or the one-to-one-interviews which were used for the instructors, were given the opportunity not to answer questions and had the right to withdraw at any stage (Brinkmann & Kvale, 2005), and reminded about their right not to answer a particular question. The identity of the interviewees was anonymized, and confidentiality was maintained throughout the study. Anonymity was achieved using a number to denote the participant, for example, Instructor 1, with the addition of minimal personal information to provide context to the study. Permission to record and transcribe the interviews was gained on an individual basis. Finally, the recordings were handled with care and stored securely.

4.15 Research Limitations

As identified above, the study was based on a sample of 12 participants, therefore, the findings of this qualitative study can only provide an indication and a potential insight into the usage of XR in training welding apprentices compared to a traditional mode of learning. While the sample size can be seen as being small, the study did generate actual data as opposed to generating a new theory only or proving or disproving an assumption. The robustness of the data and the credibility and justification of the research were important considerations. To achieve credibility, the study used focus groups to generate the data so, enabling the sharing of ideas and experiences, which then prompted others to reflect on their own experience. The usage of a focus group strategy, interviews and then the observations from the researcher also provided a further depth of understanding of the usage of XR technologies in welding training.

A key challenge of a qualitative research project is that the method often generates a large amount of rich but informative data. Therefore, the challenge is often to separate the data into themes which can be problematic. This was made more difficult as a focus group format was also used. To overcome this challenge, the focus group participants were asked before they spoke to raise their hands and then state their names clearly for the transcription process. Easterby-Smith et al. (2008) further argued that the researcher in using interview data might consider counting the frequency of words, but this is not qualitative in nature. To overcome

this potential inconsistency, the study firstly created pre-defined nodes or themes based on the literature review and then also additional nodes for new and emerging themes for grouping purposes. This strategy enabled the core coding to be completed first and then for the new themes to be revisited to ensure all themes were constantly and methodically reviewed.

4.16 Chapter Summary

This Chapter has critically justified the philosophical positionality of the study, which was based on conducting a research project, as to how spot welding could be trained at a technical training school based in the United Arab Emirates through using traditional and extended reality technology. To achieve this, the study was centred on investigating the potential benefits and challenges of applying extended reality technologies in technical education in the UAE when training welding apprentices. The Chapter has set out the purpose of the study and how the research questions would be addressed through adopting an interventionist paradigm. In setting this out, the Chapter has presented the philosophical background of the research project, including the epistemology, ontology, and axiology of the study.

The Chapter has also presented the profile of the participants, which involved 18 participants in the main study, 12 apprentices and 6 instructors, and how two inductive research approaches of using semi-structured interviews and focus groups, which were embedded into the action research methodology. The interview process and the protocol were presented including how the pilot project informed the main study. The research coding strategy and the codes used was presented, which included how the study ensured that the quality criteria of conducting a qualitative inductive study was maintained. Finally, the Chapter identified the research limitations and how the ethical implications of conducting an interventionist study was conducted.

Chapter Five
Analysis and Findings

5.1 Introduction

The central purpose of the study was to investigate the potential benefits and challenges associated with implementing XR, or virtual and augmented reality technologies when used in vocational education in the UAE to train apprentices to weld. In line with this, the following research questions were asked:

Research Question One: what are the challenges and opportunities of implementing extended realities technologies in a vocational education setting in the UAE?

Research Question Two: how does the students learning experience change when implementing extended realities technology in vocational education in the UAE?

Research Question Three: what is the instructor / trainers experience of implementing extended realities technology in vocational education in UAE?

Based on addressing these three research questions, this Chapter will present the findings generated from using an action research strategy. This will include a critical review and comparison of the experiences encountered by a small group of learners based in the UAE using traditional and XR learning methodologies. To achieve this, this Chapter will present the research strategy which involved three distinct interventions cycles during a training session.

In cycle one, the strategy was to determine the experiences of the learner and the instructors when using conventional welding equipment and resources. From the focus group which involved the learners and the semi-structured interviews with the instructors, the following themes were identified, firstly, that training traditional welding skills can enable the learner to experience the welding process first-hand and understand how to deal with the environment, and secondly, that a real workshop setting can be a distraction to the new learner.

The second phase, which was cycle two, focused on the learners and the instructors' engagement of the XR technology to train apprentices how to weld, the same interview format was followed as cycle one, and identified that virtual training could provide a medium to be an effective intermediate training tool, as the technology can assist in imparting new

practical vocational skills. However, the second cycle also identified that while VR training can be used to reinforce traditional vocational training techniques, this technology cannot replace traditional tutor-led teaching or experiencing the real welding environment.

In the final cycle, based on the findings of the first two independent phases, the research approach combined the two training methodologies. The study found that combining the training strategy of traditional and XR (VR / AR) technology can potentially provide the most effective means to train apprentices to learn basic welding techniques.

The following three sections (section 5.2, 5.4 and 5.5) will focus on each cycle in greater depth by presenting the perceptions and experiences of both the learner and instructor as to training in welding using traditional and XR techniques, commencing with cycle one which was based on the traditional mode of vocational training. It should be noted that consideration was given as to whether the findings should be presented based on the themes being grouped together or alternatively reflective of the three iterative cycles. The decision to present the findings as the cycles progressed was to follow the action research strategy, but also show the progression and longitudinal nature of the project. Finally, following a constructivist perspective to gather the data and then code the outcomes meant that to group the findings would provide a generalised as opposed to in-depth portrayal of the richness of the apprentices' and instructors' experiences.

5.2 Action Research Cycle One

The first cycle of the action research approach, the apprentices were introduced to welding from a traditional training perspective. This cycle was conducted using the conventional training methods, which involved instructing learners in gas metal arc welding (GMAW) using traditional welding equipment. During the cycle, the researcher actively documented the student's reaction to the learning experience, through taking notes based on observing their reactions as they learn the fundamental techniques. Before and following the training session, a focus group interview was set up to capture the experiences and perceptions of the apprentices.

5.2.1 Theme One: The benefits of using a traditional vocational training to teach welding

Although not directly answering the research questions as presented above, the first stage of the approach was to present the experiences and perceptions of using the current mode of

learning using conventional welding equipment and resources. Therefore, the first cycle focused on the learning experience of welding using traditional training methods, set in a formal vocational classroom setting using traditional welding equipment. The findings found that the traditional welding training had several benefits for the learner, which included that the apprentice could physically become familiar with handling the welding equipment and materials, experience first-hand safety and security requirements when welding, and gain the necessary skills in a real-life welding environment. The focus group interviews revealed a **series of themes**, which included the benefits of using the physical equipment, shown below in Table 5.1, such as the learning the fundamentals like re-calibration of the equipment, understanding the safety issues and handling of the actual resources.

Theme	Codes
Theme One: The benefits of traditional vocational training	**Skills**: Traditional welding enables the learner to actually control the welding resources, for example, using the real gas welding to re-calibrate the equipment
	Skills: Real welding teaches the user about safety and security
	Equipment: Welding with real machine requires a progression of skills and knowledge

Table 5-1 Theme 1 and codes

Code 1.1: Skills: Traditional welding teaches control of the resources such as gas calibration

Based on Table 5.1, the study's findings indicated that the apprentices perceived that traditional welding permitted them to learn more about the control of elements, such as gas calibration. Learning about gas calibration and other physical elements are essential skills needed for welding to be performed in a safe and appropriate manner. In a traditional learning environment, safety skills can be gained so that the learner can manage unforeseen circumstances in the future.

Participant 4, who had three years of experience as an apprentice, stated that the real experience in the classroom environment permitted him to gain the ability to become familiar with the equipment:

> "*A good experience that benefited us in practice, and we know how to control the machine? How? We used the nozzles; we learned how to control the gas and the type of gas. We also learned how to use the right thickness of the wire*" (Participant 4, Apprentice, 3 years' experience).

Participant 9, a technician with no experience in welding, indicated that with the traditional welding machine, he was able to get a better feel and practice the thickness of the filling wire needed. In the activity observed, the learner gained technical skills, including how to interpret the filler guide tables and then how to change the type of wire and thickness to achieve the optimum welding performance.

> "*It is preferred to start with a thinner wire gauge then once we get more confident, we can increase the thickness little by little to achieve optimum results*" (Participant 9, Apprentice, 0 years' experience).

Based on the above, the students, by using real welding materials, increased their awareness and knowledge of how to use the equipment and then were able to troubleshoot any potential calibration or safety issues. In addition, the learners were able to gain an appropriate exposure to how heavy the wire was and how it felt, essential preparation skills. These findings as to the positive aspects associated with learning how to weld using conventional equipment, partly addresses research question two as to how the students learning experience may change when implementing extended realities technology in vocational education in the UAE, but by using conventional welding equipment, before they are exposed to the XR technology simulators.

Code 1.2: Skills: Real welding is beneficial as it is very interactive

When the apprentices were asked during the focus group to reflect on their learning experience, the ability to interact with the physical equipment was seen as being important. One of the participants, an experienced learner, Participant 4, stated that the traditional welding experience was very beneficial because he was able to participate, therefore was fully engaged, and then had observed this amongst his cohort.

> "*As for the training, the training was excellent and very good because all the students interacted with the training, and they were engaged constantly. I am happy with it; the instructor did not spare any effort to provide the best training for us. It was a very wonderful experience for us. I mean, those who do*

not know welding begin to learn" (Participant 4, Apprentice, 3 years' experience).

From the observation data generated by the researcher, the learners were seen to be engaged and active since the traditional machine required the students to weld the training coupons physically. The learners also noticed that they were improving with every trial they finished, which motivated them to try to improve further after each session, as seen with Participant 9.

"*The students and I enjoyed the experience, and it was [were] good. Some students struggled with their first time in welding and need to practice more just like someone training on target shooting*" (Participant 9, Apprentice, 0 years' experience).

The interactive element of real welding is an important aspect of the vocational learning process, as the learner can gain first-hand experience and then complete a physical piece of work, such as welding a coupon. Having an interactive element to the training meant that the students were engaged and actively participated in the learning process. This was confirmed by one of the instructors, Instructor 1, who has been a welding instructor for ten years, who stated:

"I have seen that with real welding, the students gain hand-on practice and actually complete real work. They are also very engaged and active in the class" (Instructor 1, Welding, 10 years' experience).

From the comments of Instructor 1, who had extensive welding training experience identified the importance of the learner gaining the *real* experience, and that when the apprentice had hands on experience, they were more engaged providing a more positive learning outcome.

Code 1.3: Skills: Real welding teaches the user about safety and security

At the end of the first cycle, the participants were then asked to reflect on the traditional training experience as to how they gained and understood the risks associated with welding. For one participant, Participant 6, who had no previous experience in welding, stated that he understood the risks of the sparks being generated and the associated dangers of using the equipment without appropriate precautions being used, by simply experiencing the workshop environment.

"*I saw the reality of welding; I saw it in the real nature. I touched the things myself, the real machine itself, and learnt the real welding and its dangers, for example. Sparks can burn the hand, burn clothes, and burn things. What is the danger of using the same machine without considering, for example, the contexts of safety and security or safety itself*" (Participant 6, Apprentice, 0 years' experience).

While being exposed to the real hazards of the workshop enabled the learner to become familiar with the environment, as the traditional training setting showed the students the actual hazards and risks of welding due to inappropriate safety procedures being followed, due to the age of the equipment or not being calibrated correctly. This can be seen from the perspective of Participant 6, who stated:

"*It is possible that the safety equipment and helmets are old; for example, the ones we used with the colleagues were old, and the vision was not clear. I mean, the whole group suffered from using the same thing. As well as exposure to the risk of sparks*" (Participant 6, Apprentice, 0 years' experience).

The potential for accidents occurring due to the poorly functioning equipment due to its age, combined with the lack of knowledge on the part of the learner, was also highlighted by Instructor 1, who has been teaching welding for ten years. While real welding can teach the apprentice first-hand about safety and security precautions, the learners also needed to be exposed to the actual dangers, but this exacerbated by their lack of experience and their initial fears of the real welding environment.

"*I feel that there are two side of the coin. Real welding can teach my students about how to manage, for example, the safety of the machine and what to do in case of any issue. But also, since they are students and do not have experience, they can also get hurt if they get scared*" (Instructor 1, welding, 10 years' experience).

Code 1.4: Equipment: Welding with real equipment requires a progression of skills and knowledge

Training welding using real equipment can be challenging for the learner as it can be extremely difficult to gain the necessary eye and hand coordination skills which is needed to be proficient. This difficulty amongst the learners can be seen in the comments and

perspective of Participant 9, who had no previous experience in welding. At the beginning of learning how to weld is to overcome the fear of the environment while also trying to repeat the task being performed.

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> "*Of course, in the beginning, it is impossible for anything new to be easy. It must be difficult. This may be a little difficult at [in the beginning] first, but it will be easier with repetition. But it was difficult in the beginning*" (Participant 9, Apprentice, 0 years' experience).

Some of the trainees in the focus group highlighted that they experienced challenges in relation to how they used the welding equipment and how they managed and dealt with hazards which the real-life traditional working training environment provided, whether this was with the electric current, the heat generated during the welding process, or the plasma that appeared. This perspective was seen in the opinion of Participant 7, a technician with no experience stated:

> "*At the beginning, as new students, who's using the machine for the first time, it is sure that we encountered problems, how to use it, how to deal with the dangers of this device in general, from electric current or from heat emitted from the work period or from the plasma that appears in our face, as well as the proper method of using the machine. I was using the 45-degree method, which I expected would be the right way. But unfortunately, not, and you had to use the pistol perpendicular to the workpiece in order to gain decent welding results*" (Participant 7, Apprentice, 0 years' experience).

The experience of Participant 7 was also shared by a new Apprentice, Participant 6, who stated that while it was difficult initially to use the actual welding equipment, the more he practiced, the more proficient he became:

> "*In the beginning, it was difficult, especially as a first-time user. But with practice, I began to improve*" (Participant 6, Apprentice, 0 years' experience).

This perspective was also shared by an experienced learner, Participant 2, who found that welding was particularly challenging and that the use of an alternative mode of teaching, such as XR would be beneficial:

> *"In the start, I was barely able to do welding, maybe I was scared, I don't know. So, it took me time, you know. I think if I had some sort of training using another way, I would have done better"* (Participant 2, Apprentice, 2 years' experience).

During the first cycle, the interviews through the focus group identified the learners could become familiar with the equipment being used, and appreciated being shown a new welding activity during each session:

> "*The pleasure is in using the same machine and identifying how to use it and gain good valuable knowledge while also having fun. I learned something new and interesting that could benefit me in my practical and personal life*" (Participant 6, Apprentice, 0 years' experience).

Another participant with little welding experience, Participant 7, agreed with the perspective of Participant 6 above and outlined that once he had understood the basics of welding, he was able to gain new skills which improved his learning experience and level of proficiency:

> *"By the time I figured out what I was doing, my learning had increased at a very high rate. I was able to gain skills every single day. It was more about figuring out what works and what doesn't"* (Participant 7, Apprentice, 0 years' experience).

5.3 Theme 2: Challenges of Traditional Welding

Several participants (e.g., Participant 7, Participant 5, Participant 4, Participant 9, Participant 8) identified that traditional welding was challenging, and this had led to several challenges which could potentially hinder the learning experience and, ultimately, their progression. For instance, the working conditions of the traditional learning environment and the actual workshop are often not ideal for training, particularly for welding, with learners often needing to wait due to safety reasons, like for the sparks and heat to dissipate. There were also delays in the material preparation by the instructor, such as for the welding coupons, which proved to be challenging and time-consuming, together with the time needed to re-calibrate the equipment. The major challenges identified during the first cycle of the project are presented in Table 5.2 below.

Themes	Codes
Theme 2: Challenges of Traditional Welding	**Environment**: poor ventilation in the workshop made it hard to work long
	Perceptions of the task: Students have lack of confidence in using welding equipment
	Perceptions of the task: Traditional welding is very time-consuming, particularly as to waiting
	Perceptions of the task: need for more practice-time
	Perceptions of the task and equipment: visibility is an issue in traditional welding with the safety gear
	Equipment: re-calibration of the actual equipment was challenging

Table 5-2 Theme 2 and codes

Code 2.1: Environment: Poor ventilation in the workshop made it hard to work long

While there were benefits to learning in a traditional vocational training environment, the learners in the study indicated that the workshop classroom sometimes was challenging when trying to gain new skills due to the long hours needed, which was compounded by needing to wait for the instructor, and due to poor ventilation. As welding uses CO2 gas, and then generates heat, sparks, and other gases, for the trainees, is an authentic but uncomfortable learning environment, which they on reflection appreciated. This was illustrated by Participant 7, who had no welding experience, who recalled the session:

> "*Providing a means of ventilation because of fumes and gases, at the time of work, the gases were coming out, but I have no knowledge of whether there are toxic or non-toxic gases. It is preferable to have ventilation close to the location of the work*" (Participant 7, Apprentice, 0 years' experience).

Participant 4, with three years' experience as an apprentice, stated that the poor air-conditioning in the workshop combined with the heat and gases generated had made the session extremely challenging particularly as to levels of concentration:

> "*Yes, and yet there is something in the workshop, poor air-conditioning and ventilation*" (Participant 4, Apprentice, 3 years' experience).

This view of Participant 4 was also confirmed by Instructor 1, who had ten years of experience in teaching welding, as he like the learner, also experienced poor ventilation due to the lack of effective air-conditioning, which had adversely affected how the training and teaching has been conducted:

> *"You know, in the workshop, the conditions are really hard and really hot. There is very poor ventilation and usually lots of gases are produced. So, I have found it to be difficult to even teach sometimes"* (Instructor 1, Welding, 10 years' experience).

These perspectives of the apprentices and the instructors were also evident whilst observing the session. The researcher identified the workshop training environment was both very warm and humid, which was also influenced by the external hot weather of the UAE, which led to an uncomfortable learning setting for both parties. The uncomfortable nature of the learning experience was further compounded by the trainees needing to practice gas metal arc welding sessions wearing heavy personal protective equipment, thick gloves and the welding helmet, which increased the level of discomfort.

Code 2.2: Perceptions of the task: Students have a lack of confidence in using welding equipment

The learners in the study also indicated a lack of confidence while initially learning to use the welding equipment in a traditional learning setting. One of the participants with no experience, Participant 6, stated that they were unsure of their skills when welding two pieces of metal together, which was made more difficult by the heat and sparks generated by the equipment:

> "*Due to lack of confidence, doubt is generated. For example, how can he weld or how he uses it, how can he connect two pieces at the beginning of the first use*" (Participant 6, Apprentice, 0 years' experience).

Another participant, Participant 3, with no experience, also indicated initially a lack of confidence in using the welding equipment, as they were unaware of the processes and techniques needed as they did not have the knowledge to know the correct pressure and angle to be used, as often the trainer was assisting other trainees. This overall led to the learner feeling discouraged and lacked any confidence:

> "*I feel really like I don't have the confidence and I don't have the knowledge and experience to do it properly. So, when I don't perform that well, I lose more confidence. I don't feel like I know the pressure to use, you know, when welding and the angle of my hand. So, this causes a lot of lack of confidence in me*" (Participant 3, Apprentice, 0 years' experience).

The learners in the focus group recalled their initial fears of the sparks being generated when using and practising the various activities using the traditional welding equipment. Some of the learners stated that they were concerned that the sparks might burn them and would lead to serious injury. This fear of sparks remained a challenge that potentially inhibited the learning and development of the learner from being proficient in the techniques needed. It also took some time for the apprentice to get used to the sparks:

> "*The first time in my life, I held a welding machine. I mean, the first thing when I saw the spark, I was afraid of it because I thought it would burn me when it started hitting me; this was in the first time. However, the second time, I began to get used to it and know how to deal with it*" (Participant 8, Apprentice, 0 years' experience).

Apart from being wary of being injured by the sparks generated, some learners were also scared of the electricity, and the noise made. For instance, one participant, Participant 5 stated that he feared the electricity being generated and the sound made by the welding equipment. However, Participant 5 also noted that while he feared the sparks and electricity, he was able to overcome these fears through the training session, and as he became accustomed to the environment, they were able to complete the welding tasks:

> *"Honestly, this was a special experience; I broke my fear because I also fear electricity. Afraid of the sound of electricity. My first problem was how I would deal with my fears of electricity and sparks. However, I faced my fears when I started training with real welding equipment, and I started to know how to deal with it"* (Participant 5, Apprentice, 0 years' experience).

Participant 10 agreed with Participant 5, highlighting that the sparks that are generated during the welding process were very off-putting when learning new techniques and skills,

particularly for a someone who had never experienced this setting before. Participant 5 stated that even if they were wearing PPE, it was still scary for them, and the sudden charge of electricity was also off-putting:

> "*Yeah, even for me, the sparks are the main issues I feel. Even if wear proper gloves and all the safety equipment, I still get scared of sparks. I feel like I will get burned. Also, the electricity that comes when the metals touch is very scary. I have seen many of my fellow students also get scared, especially in the beginning*"
> (Participant 10, Apprentice, 0 years' experience).

The presence of sparks being seen as a challenge for the apprentice learners was also observed by the researcher, with many of the apprentices giving the appearance of being afraid of the sparks and the sounds generated by the high voltage. The researcher noted that some of the learners were visibly nervous and would get startled due to the high amount of noise generated by the electricity.

Code 2.3: Perceptions of the task: Traditional welding is very time-consuming.
Welding in a traditional setting was also considered to be extremely time-consuming. One learner with no experience, Participant 9, stated that there were delays for everyone in the group, as the process involved the welding activity being taught on a one-to-one basis. The welding two pieces of metal in a straight line would mean that one apprentice could take up to at least seven to eight minutes to complete the task while the other learners could only look on and wait:

> "*Also, the few numbers of machines, for example, if we have a course with 20 students, then we need to have many machines running at the same time, and we experienced delays and waiting time because the first thing you start to practice welding is the straight line in a metal, so this would consume much time, and each student needs at least seven minutes to 8 minutes or sometimes even 10 minutes per pass*" (Participant 9, Apprentice, 0 years' experience).

This perspective of Participant 9 was shared by Participant 2, who had two years of experience in welding, and stated that it takes a long time to modify the equipment and work on the welding task, particularly when the equipment was not working correctly due to

calibration issue and its age. This limitation of time and the equipment needing to be re-calibrated could potentially hamper the learner to become proficient in the necessary skills needed:

> "*The first issue with real welding is that it takes much time to adjust the device and work on the welding machine to eliminate the issues in the settings. For example, we are supposed to start from 8:30, meaning the coach must be there at 8:00. We start welding. The first one is welded at 9:50 on the first day, right, yes, I took time to adjust the device because this is a waste of training time. And the second thing is that we have accomplished all that we have accomplished. Welding with the normal machine at a rate of 2 pieces per student except for the only one that did 3, which, as I see, is not enough for the student to reach the required skill. This means that you need more time to train*" (Participant 2, Apprentice, 2 years' experience).

The focus groups also revealed that the learner's long waiting times were mainly because of the instructor's needing to prepare each traditional welding machine for the apprentice with the correct settings, leading to the students losing their focus whilst waiting. For instance, Participant 9 stated that:

> "*There was a long waiting period, during the training of welding with conventional machines"* (Participant 9, Apprentice, 0 years' experience).

Code 2.4: Perceptions of the task: The need for more practice

Another challenge identified during the focus group interviews of the first cycle was related to the student learner's lack of hand stability, a skill which needs to be practised and rehearsed. However, many of the apprentices, perceived that they had insufficient time to learn this skill due to the number of other trainees wanting to use the resources.

> "*We need time to stabilize the hand and stop the shaking or trembling. This is the most important thing*" (Participant 6, Apprentice, 0 years' experience).

This lack of time to practice and gain the level of hand stability proficiency was highlighted by an experienced learner, Participant 4, who stated that he had to rehearse and practice constantly to learn to weld in a straight line because his hand shook a lot. Participant 4 also

noted that even a small movement was enough to change the direction of the welding line, which is really something that the participants struggled with:

> *"I have real difficulty in doing welding in a straight line as I feel that even if I move my hand a little bit, it will go wrong. Managing my hand for this is very hard as my hands shake a lot"* (Participant 4, Apprentice, 3 years' experience).

The need to prepare the materials needed and then the limited availability of the equipment used for the training activity, together with the time required to gain the skills using traditional welding resources, meant that the learner's time to practice was limited. The high level of time needed to prepare for the welding activity meant the students did not have sufficient time to practice and develop their skills, as indicated by the perception of a learner with no previous experience in welding, Participant 6 who stated:

> "*It was slow. I mean, as I told you, it was possible to feel the lack of previous practice. Need more time and skills, more training, more preparations to get the metal pieces ready for welding, preparation for the machines with wires and gases too*" (Participant 6, Apprentice, 0 years' experience).

The researcher also observed that out of the four-welding resources located in the workshop setting, only two were functional, indicating that there was a limited number of resources available for the learners to practice on. This was also highlighted by the instructors, who noted that two of the resources were not calibrated correctly, and needed to be repaired, which resulted in the training session using half the allocated resources:

> "*This happens quite a lot where we have actually four machines in the workshop, but two of them are out for repairs and we are using only two machines*" (Instructor 1, Welding, 10 years' experience).

As for the material preparation time, the learners recalled that the amount of time needed for this process to be completed, which was essential for learning how to weld in a vocational setting, was seen as comparatively lengthy. This process involved the instructor needing to prepare the welding coupons for each of the students, together with additional materials if

required. However interestingly, as the focus group interview progressed, it became clear that the students were not aware of the time needed for material preparation.

> "*I feel it at the time of welding the iron plates [pieces] with rust on them, and what I know is that the rust is not good for welding since the weld will not be strong. Of course, before welding the straight line, you must ensure the two pieces are aligned. But if they were rusty, the sparks would go everywhere, and the weld will not be good, I noticed*" (Participant 8, Apprentice, 0 years' experience).

It was also observed by the researcher that the instructor spent a considerable amount of time preparing the materials and the equipment, which led to many of the apprentices losing focus on the training task. This was also recognised by the instructors, who highlighted the time needed for the preparation of the materials, which led to the learner losing their concentration or preventing them from practicing their newly acquired skills. This was captured by the view of a welding instructor who had 10 years' experience, Instructor 1:

> "*Preparing the welding coupons is very time consuming and often I see that when I am doing the preparation, the students are wandering in the workshop and are generally bored*" (Instructor 1, Welding, 10 years' experience).

The above findings are also reflected in the researcher's observations which included that approximately half of the cohort of learners were either wandering around or sitting down and not engaged in the learning experience. With only two welding resources working, this resulted in increased downtime for the learner being able to practice their new skills. It was estimated that, on average that each learner needed to wait for ten to fifteen minutes before they could undertake the next task or practice their new skills. It should also be noted that the total session duration was scheduled for three hours only.

Code 2.5: Perceptions of the task and equipment: visibility is an issue in traditional welding with the safety gear

Being able to see the welding process and the theme of visibility emerged as a significant challenge for most of the learners using the traditional welding resources. The lack of visibility was due to the use of safety gear or PPE being mandatory. The learner's highlighted that their vision had been impaired due to the shaded glass used in the welding helmet, which

although protecting their eyes, also prevented them from seeing what was being welded and had hampered them from being able to weld in a straight line, as seen with the comment of Participant 5, who is a new apprentice technician with no experience:

> "*The vision is also important. How not to wear the same clothes and deal with the machine. This is what I like. It has to be in terms of how hot it is? What is the wire to be used? Any wire? What do I do with the machine itself? This is a skill on its own that requires practice. Also, the challenges. It is how to deal with sparks and electricity, and this is what I could not control because I am afraid of electricity and sparks. It is a big challenge that I overcame yesterday*" (Participant 5, Apprentice, 0 years' experience).

The perspective of Participant 5 was supported by Participant 8, who had no previous experience in welding. Participant 8 added that while he thought he was welding in a straight line, due to his limited vision, the welding zigzagged. For Participant 8, this was due to the darkening level of shading, which was part of the safety equipment, which made it harder for the learner to see, practice and learn how to coordinate their hand movement during the welding process:

> "*And the second thing when I start welding, in the beginning, I was not focused and thought I welded a straight line. When I took off the glasses, I was surprised that my weld was zigzagging right and left and not in a straight line*" (Participant 8, Apprentice, 0 years' experience).

It was observed by the researcher during the first cycle that several of the learners consistently voiced their frustration, that although the safety glasses' shading level was set to its minimum, they were still unable to see the welding process through the welding helmet.

Code 2.6: Equipment: the re-calibration of the equipment was a challenging

The calibration of the equipment proved to be a necessary challenge in a traditional welding setting for many of the learners because the gas ratio and the wire feeding for the welding equipment needed to be accurately calibrated. Any inaccuracy in the calibration would result in the welding coupons being inaccurately welded, as observed by Participant 9:

"*In terms of calibration, the calibration of the welding machine was also a challenge. The gas ratio meter is a challenge. Additionally, the wire and the appropriate wire feed. I mean, for example, the best thing would be the begin the training with small and lighter wire because the strong wire was a little long, causing holes in the metal during welding. I mean, these are some challenges that we faced generally*" (Participant 9, Apprentice, 0 years' experience).

Some of the learners saw using the real welding equipment as assisting them in understanding the calibration process due to practising on the physical equipment.

"*We learnt how to calibrate the welding machine. How to open the gas nozzle. Is the gas type, okay? How to identify the correct wire gauge to be used*" (Participant 4, Apprentice, 3 years' experience).

5.3.1 Summary of the Research Cycle One

The first cycle of the study generated a critical insight into how apprentices' experienced learning how to weld when using the actual workshop environment and the physical resources. The usage of the conventional training environment was informed by the earlier research of Golbabaei and Khadem (2015), who highlighted the necessity for learners to learn in the actual welding environment. In this conventional setting, the apprentices were exposed to the noise, the heat and associated distractions like the sparks which occur when welding, which were seen as being beneficial from both the learners and instructors' perspectives, a theme identified as important by both Moro et al. (2021) and Nasir et al. (2011). For the learner they were exposed to handling the actual equipment, which can be heavy, and then having an awareness of potential safety issues, which was an important facet for the instructors. However, training in the real welding environment has also identified limitations or challenges, including the need and time to practice, which for the learner, was a particularly important aspect when acquiring the right hand-eye coordination skills. But the time available was limited due to the learner needing to wait as the process was often based on a one-to-one basis, then compounded by the fact that the instructor often needed to stop the training session as they needed to get more resources as the activity progressed. There was also the challenge associated with the poor ventilation in the workshop, making the learning

process difficult for the learner, a theme earlier identified by Chakradhar et al. (2022) and Lambardi et al. (2005, 2009). Linked to this was the difficulty associated with wearing of the PPE which needed to be worn, such as the welding helmet, which slowed down the learning process as to how to weld precisely. There was also the perception that the enviroment and the welding workshop setting resulted in the apprentice feeling they lacked the confidence and were unable to master the fundamental psychomotor skills needed to weld. This lack of confidence was present when the learner's reflected on the need to re-calibrate the equipment, which became a challenge when faced with the conventional welding workshop environment.

5.4 Action Research Cycle Two

Having completed the first action research phase, the researcher organised the second cycle, where the training was conducted using only the virtual reality simulator in the VR setting. To conducting this second cycle, the study was specifically focused on the three research questions. **Research question one**: what are the challenges and opportunities of implementing extended realities technologies in a vocational education setting in the UAE? **Research question two**: how does the students learning experience change when implementing extended realities technology in vocational education in the UAE?, and R**esearch Question Three**: what is the instructor / trainers experience of implementing extended realities technology in vocational education in UAE?

The learners used the reality welding simulator, known as SOLDAMATIC, which was used to instruct the learner in using gas metal arc welding (GMAW) techniques, which were similar skills learnt during the first action research cycle. During the second cycle, observations by the researcher were documented as the training session commenced, with the focus group of the learners interviewed before and after the second cycle, while the instructors were interviewed post-session on a one-to-one basis.

5.4.1 Theme 3: Virtual training can assist as an intermediate training tool

The first theme to emerge from the second cycle was that many of the learners' indicated that the use of VR training could improve the overall learning process. The learners identified that the use of virtual training could become an important training tool which could assist them in practising without the safety issues associated with welding. There was also the recognition that XR technology could save on materials and enable the learner to practice more often. Finally, the learners also noted that VR could help to remove the wariness of sparks which are often generated and the noise of the electricity, so enabling the learner to focus on gaining

new skills and becoming more competent. Table 5.3 below sets out the codes used to group the themes which emerged from the findings.

Themes	Codes
Theme 3: Virtual training (XR) can assist as an intermediate training tool	**Perception of the task**: XR can help save materials and time
	Perception of the task: XR technology may help in gaining basic skills before real welding
	Perception of the task: XR training can remove the fear of heat for the students
	Perception of the task A standardised process is necessary for XR

Table 5-3 Theme 3 and codes

Code 3.1: Perception of the task: XR can help save materials and time

As XR is a virtual environment in which the welding process is conducted in a simulator, the learners and the tutor highlighted that there was no need to prepare and use materials for the lesson, which included a large amount of CO2 needed to power the welding process. Participant 4 one of the apprentices, highlighted that if the use of VR is applied at the beginning of the training program, the learner can gain basic skills and knowledge without needing to use any physical materials or gas waste while learning the basic skills needed.

> "*As for the VR, you will gain in saving materials and save time. I knew that we lost the iron right of the instructor, and we lost the gas. These things are learnt without loss when using VR equipment. Okay. You have semi-real training but without loss. We appreciate, as Participant 9 said, that we start with a VR, and it is better to do so based on reducing costs, and the same thing is to gain experience, as he said, at least 40%*" (Participant 4, Apprentice, 3 years' experience).

Participant 10 agreed with Participant 4, who stated that VR permitted him to engage better in the welding activity but also did not need the actual physical material. For Participant 10, he recognised that the traditional welding methodology needed to have physical materials made available, and this tended to slow down the process. Linked to this was also the lack of fumes and gas being released, which occurred during the traditional training welding lesson, which

can cause health and general well-being issues for the learner in the workshop. Furthermore, the gases and the noises generated were also off-putting.

> "*We spend more oxygen gas and on consumed materials. I mean, based on what we intend to learn so that one can do this training through the VR first, and then, we go to the real training*" (Participant 10, Apprentice, 0 years' experience).

Participant 8, who had no welding experience, agreed with both Participant 10 and Participant 4, who stated that there is a lot of waste material generated when learning in a traditional training setting and there was a lot of time being lost, which was not the case with XR (VR).

> "*We have wasted much material in the traditional training. The VR simulator is better"* (Participant 8, Apprentice, 0 years' experience).

XR may not only be used to save materials and enable the learner to practice essential skills but also assist in exercising the muscles and maintaining control of speed, angle, and distance while welding, therefore enhancing muscular memory, as seen with the comments of Participant 1, who had four years of welding experience:

> "*The only thing that can resemble reality is virtual training, which can save materials and help you exercise your 'brain' muscles and maintain control of speed, angle and distance while welding, improving muscle memory*" (Participant 1, Apprentice, 4 years' experience).

Participant 5, stated that he had acquired the skills to perform the task at a lower cost but also in a shorter amount of time, making the experience in some way more beneficial compared to the traditional welding method:

> "*Also, the skills will be gained with less cost of materials and less time even better than if you are training in real welding and you do 4 to 5 coupons of real welding*" (Participant 5, Apprentice, 0 years' experience).

Participant 2, with 2 years' experience in welding, agreed with the other participants, particularly if the VR environment was used first to gain basic skills, particularly psychomotor skills. The participant also noted that gaining psychomotor skills when using

virtual training and then fine-tuning these skills when being trained in the real welding environment:

> "*The first thing you need to do is some VR training to acquire the skills. I mean, the first thing should be training in virtual reality to gain a skill, which is related to the muscle memory [psychomotor skills] mentioned by Participant 1 and then to train in the real welding machines*" (Participant 2, Apprentice, 2 years' experience).

Focusing then on the skills gained by using XR technology and then compared to those learnt in a real welding setting, for Participant 3, who was a novice learner, stated that training in a virtual reality environment should be the initial step to acquiring a skill, which can then be built upon when using the traditional method.

> "*In the beginning, just like the PlayStation, you must acquire the skills that require you start welding from speed and then control the distance between the workpiece and welding gun. Then, when you work on the real piece, you can develop the skill day after day*" (Participant 3, Apprentice, 0 years' experience).

In summary, based on the findings generated from the second cycle, VR was seen to enable the learner to gain the necessary skills as it permitted the individual to learn to weld accurately, angle their hand appropriately and apply the correct pressure. For the instructor, there was an indication that the use of XR technology ensured there was no need to prepare the materials in advance, such as the preparation of the welding coupons, which sometimes meant that training time was lost.

> "*The welding pieces need to be organized and cleaned, which requires a lot of effort and time. And some pieces, although they were cleaned, some pieces will start to rust quickly, unlike preparing a piece for traditional welding, it will be ready and clean in VR*" (Instructor 1, Welding, 10 years' experience).

Code 3.2: Perception of the task: XR technology may help in gaining basic skills before real welding

Several apprentices who had no previous welding experience (e.g., Participant 9, Participant 10, Participant 5, Participant 8, and Participant 6) agreed that using VR technology helped them to gain basic skills, which could have been useful before they used real welding

equipment and materials. Participant 9 also stated that virtual reality welding enabled him to gain basic hand movement and a familiarity with the handling of the welding pistol. Participant 9 also noted that completing the first round of training in XR could improve his level of competency by 40-50%, as he had checked his performance on the screen, compared to learning using only traditional welding equipment:

> "*Of course, it is the best thing to do with virtual reality itself; as we said before, it is better to use virtual reality technology to learn the skill of hand movement. How do you handle the welding pistol? These things, for example, are like these things, then, because when he turns to work on the operator, he will not come down for the workshop and starting to work in the same place, he will have gained experience, at least something that means 40% to 50%, and the work completely acquires the rest*" (Participant 9, Apprentice, 0 years' experience).

Participant 10 agreed and elaborated that continued training and development using XR had improved his skills significantly. Using the VR environment, the learner was able to practice the welding process four to five times more than the traditional mode, therefore improving his hand eye coordination and movements.

> "*With time and with continuity, the training improves the skills. In the beginning, the first experiment, I was not good at welding, but in the second, third, and fourth time, the skill improved in the welding with the real machines*" (Participant 10, Apprentice, 0 years' experience).

For Participant 5, he noted it had been initially challenging to work with the real welding equipment. Part of the reason for this reflection, was due to the uniqueness and unfamiliarity of the environment, where the learner had to cope with the restrictive space and the welding parameters and to have command over the equipment and the surrounding environment, which included sparks and a high level of noise. The participant also highlighted the preference that prior to using the real welding equipment, a training lesson using VR would be more suitable.

> "*It was difficult to deal with the real welding machines at first. Because the environment was new, one had to deal a little with it to break this topic to learn about the right distances, learn about right welding speed and control them. The best for the*

trainee is to learn with VR before he goes to the real welding machine" (Participant 5, Apprentice, 0 years' experience).

However, Participant 1, who had some experience in welding added that in a virtual reality setting, while it helps the learner to gain the basic skills of hand angle and speed required to weld accurately, the technology cannot fully replace using the real equipment, as welding could not be learnt only using a virtual training mode.

"*The VR benefit is teaching angle, distance, speed, but it is not real. Because with the real welding if you do not weld with the correct angle, you will miss up*" (Participant 1, Apprentice, 4 years' experience).

This was partly contradicted by Participant 8, who also had no experience in welding, as he believed that conducting VR before the introduction to using real welding equipment would enable the apprentice to learn to hold the nozzle straight and gain an insight into how to grip the nozzle properly, an essential fundamental skill needed, which was often difficult to gain when using the actual equipment:

"*I see VR at first is better. To learn the welding safety first and then the names of welding components. I see that starting with VR is better. Because you learn how to hold the nozzle right. And you learn the distance between the grip and the handle, which is very important at the beginning"* (Participant 8, Apprentice, 0 years' experience).

A similar perspective was provided by another novice learner, Participant 6, who identified that VR could provide the learner with clarity on the fundamentals of how to solder or handle a welding gun. For example, how to weld at the optimal speed or angle to ensure that the weld works.

"*It may be in terms of use, it is possible from the method of welding or the method of the grip, the method of how-to holding welding gun, what do they call the pistol or whatever. For example, how to get the right speed that can be more accurate, the angle, and the angle will be correct so the weld will adhere*" (Participant 6, Apprentice, 0 years' experience).

Most of the apprentices agreed that using XR training initially would have helped them to gain the fundamental skills earlier before embarking on using the actual equipment in the traditional training setting. For these learners, virtual reality could have assisted them in acquiring the fundamental skills of how to position the hand when welding, understand the distance needed when undertaking the task and practice the speed needed to weld effectively. The apprentices agreed that introducing virtual reality prior to undertaking practice tasks in a welding environment would be beneficial, and this informed the third cycle of this study.

Code 3.3*:* Perception of the task: XR training can remove the fear of the environment for the students

Emerging from the findings was the benefit that VR training offered the medium which enabled the apprentice to learn the basic skills but without the external distractions, like the heat and sparks being generated from the welding process. This perspective was captured by the view of an inexperienced learner, Participant 8, who outlined that he was initially wary of the traditional welding setting as he was distracted by the heat generated from the welding equipment, which slowed down his rate of learning. Participant 8 stated that if he had learnt using VR first, without the sparks and the heat, then he would have progressed and gained the fundamental skills faster, as the external distractions were off-putting.

> "*I faced issues with learning as the heat distracted me. Welding speed was also an issue for me. If I had used the VR that day, I could have learnt better and faster while being able to control the speed better*" (Participant 8, Apprentice, 0 years' experience).

Participant 9 agreed with Participant 8, who noted that using VR at the commencement of the training session could have mitigated or limited the learner's initial wariness due to the external environment, as this would enable the individual to become more accustomed to the basics before introducing the real sound and the vibrations associated with welding later:

> "*There is a benefit; I mean you can break a student's first-time fear by allowing them to use the VR first*" (Participant 9, Apprentice, 0 years' experience).

Code 3.4: Perception of the task: Standardised process is necessary for XR

While the apprentices recognised that XR provided them with the means to improve their welding skills, the learners also indicated that a standardised process of training was necessary when being trained using VR technology. This was illustrated by Participant 4, who had three years of experience in welding. Participant 4 observed that all the welding equipment, whether it was the actual physical resource or virtual, needed to have standardised settings set in advance and that the instructor had sufficient time to prepare the training session.

> "*I prefer that each machine or all the welding machines be standardized with the same settings and gas and the same type of wires to make everyone sure of what he is going to deal with. And maybe the instructor did not find the time to prepare all that while preparing the pieces of beads and coupons*" (Participant 4, Apprentice, 3 years' experience).

The need for standardisation and time allocated was also shared by the instructors, who stated that there is a need for the development of a standardised XR setting so that the wires and the welding gun can emulate the real welding equipment. Instructor 1 also added that using similar wires and equipment could assist in this familiarity process.

> *"I think there is more standardisation between the VR and traditional machines that is needed. If the wires and the elements of the machine are the same, the students will find it easy to apply what they have learned from VR to real"* (Instructor 1, Welding, 10 years' experience).

Based on the above, both the apprentices and instructors agreed that the use of XR in learning how to weld could be beneficial to gain the fundamental skills compared to traditional welding training practice. The apprentices saw that the usage of virtual reality could reduce waste and provide them with valuable time to practice. Through using XR, the technology did not need to have CO2 gas being used, and it cut down on other materials needed to be prepared. However, to enable XR to be effective, there was also a need to have a standardised environment which closely emulated the real welding setting. While XR potentially could assist the learner in gaining the fundamental skills needed for welding, such as understanding the correct angles to weld and the necessary distance needed to stand, there was a recognition that XR cannot replace the traditional learning environment.

5.4.2 Theme 4: XR can help to gain the necessary fundamental coordination skills

From the findings generated through the second cycle, there was evidence to suggest that XR assisted the learner in gaining the necessary skills and expertise which could be applied in a welding setting. The learners indicated that XR could help them with gaining hand stability skills and to gain fundamental welding skills faster. Table 5.4 below sets out the codes developed as part of this theme.

Themes	Codes
Theme 4: XR can help impart necessary skills	**Perception of the task:** XR can help with hand stability
	Perception of the task: XR can be used for fine-tuning skills
	Perception of the task: XR can help if the time available for training is short
	Perception of the task: XR skills translate into real-world skills

Table 5-4 Theme 4 and codes

Code 4.1: Perception of the task: XR can help with hand stability

The learners in the focus group indicated that learning welding through XR technology permitted them to gain greater balance and skills in hand stability and strengthening hand muscles. An inexperienced learner in welding, Participant 8, stated that XR or VR had helped him to stop his hands shaking, which had occurred after using the traditional welding equipment and due to him being nervous:

> "*If your hands shake, it can help you learn how to stabilize your hand. I mean, it helps me to learn how to weld with the right distance between you and the metal*" (Participant 8, Apprentice, 0 years' experience).

This experience was mirrored by Participant 6 who noted that he was able to correct his hand movements more rapidly when using XR compared to when using the traditional welding equipment.

> "I was able to understand what I was doing wrong and improve my hand stability greatly" (Participant 6, Apprentice, 0 years' experience).

Apart from hand stability, Participant 5, noted that XR permitted him to learn and understand the most optimum distance needed to be maintained between the welder and the metal.

> "*I mean, as the guys mentioned, the VR trains you on the correct hand positioning and the proper way to hold the welding gun*" (Participant 5).

Participant 1, who was experienced in welding, stated that he was able to gain faster understanding of the distance needed for how far the rod needed to be from the welder while also enabling him to practice hand movements:

> "*I was able to learn how to position my hand correctly and how far I should stand for the rod to be in perfect position*" (Participant 1, Apprentice, 4 years' experience).

Code 4.2: Perception of the task: XR can be used for fine-tuning hand and eye skills

The participants in the second cycle indicated that XR could be used to ensure that fine-tuning their hand and eye skills were acquired. This was illustrated when the apprentices recalled their experiences during the first cycle in the traditional welding class and how the XR experience had assisted them in improving the skills learnt since the first cycle. One participant, Participant 5, stated that while the real-world training provided him with one skill, for example, how to hold the welding gun or how to do welding in a certain direction, using the XR simulator enabled him to learn multiple skills and permitted him to further refine these newly learnt techniques.

> "*I mean, when you have training in the actual workshop, you can learn how to handle the welding gun. All of these details you can learn in the actual workshop. Once you have mastered these skills, you can train via VR simulator*" (Participant 5, Apprentice, 0 years' experience).

Participant 4, who had ten years of experience, added that he had gained the necessary skills and learnt how to weld in a straight line after being trained in the VR simulator.

"*If you have noticed, we were able to learn how to weld in a straight line after being trained in the VR simulator. The simulator helped us in that*" (Participant 4, Apprentice, 3 years' experience).

Adding to this experience, Participant 4 stated that using XR promoted, for him, a sense of self-confidence through gaining and reinforcing the newly acquired welding skills.

"*Self-improvement. We discussed the advantages of VR training and the problems to avoid. The essential skills gained through VR technology are great, and the trainer is not required to follow up on our mistakes*" (Participant 4, Apprentice, 3 years' experience).

From the findings above, VR has the potential benefit of allowing the learner to work on fine-tuning their eye and hand skills. It was also observed by the researcher that these learners tended to practice welding the V-shape coupons using the XR simulators in pairs according to the welding tests developed by the manufacturer of the technology. These tests and results could then be uploaded into the system and were based on identical tasks compared to undertaking real welding projects. With the XR simulator, the learner was also faced with real-time on-screen assistance icons to various master manual skills such as arc length, travelling speed, distance, and angles, in addition to voltage, current, intensity, and wire speed, all fundamental to welding.

Code 4.3: Perception of the task: XR can help if the time available for training is short

The learners when asked about their experiences associated with practice time, compared their experience to the traditional environment in cycle one. For the apprentices, the traditional method of learning was restricted by the high preparation time needed by the instructor, while XR was seen as being more readily available to practice on. Participant 8, with no prior experience, stated that when he was trying to gain the skills and practice in a real-world setting, it was far lengthier compared to using XR.

"*If time is short, virtual reality training is preferable. If a person can learn from traditional training, he will most likely benefit from VR instruction as well*" (Participant 8, Apprentice, 0 years' experience).

From the findings above, XR permitted and enabled multiple apprentices to train at the same time. This was illustrated by a new technician apprentice with no experience, Participant 7, who stated XR enabled him to weld 12 to 15 coupons in the two days of training when using the XR simulator compared to only 2 to 5 coupons when using traditional welding resources.

> "*In the previous year, the number of trainees has grown. 5 trainees can be trained simultaneously. This can never be done in a real workshop. It is really dangerous*" (Participant 7, Apprentice, 0 years' experience).

Code 4.4: Perception of the task: How XR skills translate into real-world skills

As to how the XR learning experience can be applied to a real welding setting, two of the participants, Participant 2, an apprentice, two years' experience, and Participant 4, an apprentice, also with three years' experience, highlighted that the use of XR allowed the learners to gain the skills that they could potentially apply to traditional welding with a high degree of success:

> "*I would like to point out that in the VR simulator, you can adjust the voltage automatically. While in the actual welding machine, you cannot do so. One should learn how to do these tasks in reality*" (Participant 2, Apprentice, 2 years' experience).

Participant 4 also indicated that VR provided him with a significant degree of coordination skills and confidence compared to what had been learnt in the traditional training session which was conducted in cycle one. In illustrating this, Participant 4, qualified this by saying he had gained 80% of the knowledge from the XR and only 20% from using traditional training, but this could not be verified.

> "*More than I had anticipated. As someone who knows very little about welding, I believe I have learned a lot in a short period of time. The VR training accounted for 80% of it, while the practical experience contributed 20%*" (Participant 4, Apprentice, 3 years' experience).

From the findings, it seems that the learner using virtual reality enabled them to practice and improve their fundamental skills, like for example, hand-eye coordination. When compared to more conventional methods of training, such as welding, the learners saw that XR enabled them to adjust their hand movements more accurately.

5.4.3 XR training conducted first, followed by traditional training

As mentioned above, the study also identified that the sequence of training should commence with XR first, as this technology could enable the learner to undertake the training without any distractions, while also tracking mistakes in real-time and then using the technology to assist them in correcting the errors. XR also enabled the learners to overcome the fear of welding while gaining the essential skills of hand and eye coordination, which are shown in Table 5.5 below.

Theme	Codes
Theme 5: XR training can be provided first, followed by traditional training	**Perception of the task:** XR or VR allow to track mistakes and assist in correcting them
	Perception of the training sequence: Better to start with XR first, followed by traditional
	Perception of the task: XR can help with overcoming the fear of welding
	Perception of the task: Gained more skill in XR

Table 5-5 Theme 5 and codes

Code 5.1: Perception of the task: XR or VR allow to track mistakes and assist in correcting them

In illustrating the benefits of XR, Participant 7 and Participant 9, both with no previous experience, highlighted that the technology enabled the tracking of mistakes and assisted the learner in correcting them. For instance, Participant 7 stated that XR technology allowed him to gain feedback instantly and in real-time, which enabled him to correct his mistakes, compared to the traditional training setting where errors were detected only after the coupon had been welded.

> "*The program will do so. VR technology allows us to collect feedback very quickly. Our weaknesses and strengths are displayed on the screen*" (Participant 7, Apprentice, 0 years' experience).

Participant 9 agreed with Participant 7, also recognising the benefit of XR in detecting mistakes in real-time.

> "*While you are using the VR training, it instructs you. The red and green lights point to your mistakes and assist you in correcting them*" (Participant 9, Apprentice, 0 years' experience).

From the researcher's observation of cycle one compared to cycle two, once the learner completed their welding activity, the instructor in the traditional learning setting needed to give comments on how the welding outcome was based on the completed coupon whilst using the AR/VR simulator, there was a report produced, which included information on angles used, speed, and distance, which could be used to inform the tutor as to the learner's progress.

Code 5.2: Perception of the training sequence: XR commences first, before the traditional training

As highlighted above, the learners, after using the XR training session felt that the technology training environment should be used first to train the basic skills, and then the skills and techniques learnt are then applied in a traditional welding setting. This was encapsulated by the comments of Participant 9, who had no experience in welding:

> "*For the VR training, I believe it was sufficient; still, it is better to begin training in the VR and then go to the workshop to put what you have learned into practice*" (Participant 9, Apprentice, 0 years' experience).

An inexperienced learner, Participant 7 supported this perspective of Participant 9, by adding that by using the virtual reality training environment, he was able to significantly expand his skills and knowledge. The apprentice also noted that if he had started the training with VR, his level of accomplishment of the basic tasks and techniques would have been gained potentially in a shorter period.

> "*It is a fantastic idea to begin our training with virtual reality. If we had worked in the workshop, I believe we would not have been able to accomplish what we have through VR training. We have learned a lot while using the VR training*" (Participant 7, Apprentice, 0 years' experience).

The learners concluded that the curriculum should be designed so that the XR training commenced before entering the actual welding workshop. Participant 7 outlined that starting with the XR training as the first step was the most logical strategy, which would mean that the trainee learnt the fundamentals before being exposed to the traditional training setting and resources.

> "*One should start with VR training then move on to the practical training. I believe that once I have reached an intermediate level, I should enrol in a practical course*" (Participant 7, Apprentice, 0 years' experience).

Participant 2, who had two years of experience in welding also outlined that the optimal mix between XR and traditional modes of training should be equal or 50-50, therefore the trainee would have half their training in XR and the other part in the physical workshop.

> "*We need 50% VR training and the rest for traditional welding equipment training*" (Participant 2, Apprentice, 2 years' experience).

In contrast to Participant 2, Participant 7 contended that instead of going for a 50-50 split of the two modes of training, the instructor should introduce a mix of 30-70, with the lower percentage being for VR and the higher percentage allocated to traditionally training welding.

> "*30% - 70% or let's say 30–40% for VR – 70-60 % for the traditional course*" (Participant 7, Apprentice, 0 years' experience).

Building on this, Participant 10 stated that the curriculum should be designed in such a way that the learners are introduced to XR first, which is followed by training the apprentice with the real welding equipment using the traditional methodology.

> "*First, start with the basic with VR, then cover the real welding machines, after that the practical training*" (Participant 7, Apprentice, 0 years' experience).

Participant 1 highlighted that he gained his skills and techniques while using the simulator, but he also needed to have exposure to real resources. Reflecting this, he recommended that the XR simulator and the real welding resources should be used in tandem so that skills gained can be transferrable.

> "*The more I work with the simulator, the more I feel I improve my technique. In addition, I found out that, especially when I work directly after using the Simulator and go to the workshop, my skills are sharp right after*" (Participant 1, Apprentice, 4 years' experience).

The consensus was that XR technology should commence before traditional training, as the learners felt that it is preferable to first train in XR and then attend the workshop class to apply what was learnt when the fundamental skills and techniques are gained.

Code 5.3: Perception of the task: XR can help with overcoming the fear of welding

Several participants, including Participant 9 and Participant 6, both with no experience in welding, noted that XR training helped them to overcome the fear of using the welding equipment. Participant 9 stated that VR training could enable the basic skills and techniques to be learnt without the fear or distraction of using a real welding resource.

> "*One more thing, at first, the VR training is better; it helps you overcome the fear of using the welding machine*" (Participant 9, Apprentice, 0 years' experience).

An inexperienced learner, Participant 6 stated he was initially afraid or wary of the sparks and the electricity sound being produced with the real welding equipment, however, he did note that although XR had enabled him to overcome this fear, it was essential to experience the real environment.

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> "*In VR, you know that you are safe I mean no sparks will hit you and no harm will befall you. You are dealing with the VR setup comfortably*" (Participant 6, Apprentice, 0 years' experience).

Code 5.4: Ability to gain the fundamental skills using XR

As to the ability to gain the necessary skills, Participant 10, Participant 9, and Participant 8, who had no welding experience and Participant 2, who had two years of experience in welding, provided an account as to how they gained the basic skills and techniques through XR compared to the traditional welding workshop environment. In illustrating this, Participant 10 saw that he was able to acquire the concepts of understanding the angular

distance between him and the metal coupon, while also applying the correct pressure needed whilst using the VR training resources.

> "*I think we have learned the essential skills in the VR. Know how to work with each piece in accordance with the angle and the distance between you and the piece. We learned it all through –the virtual reality simulator. After that, we could apply everything in the actual workshop*" (Participant 10, Apprentice, 0 years' experience).

Participant 9 highlighted the simplicity of learning through XR compared to using traditional welding equipment:

> "*It was simple. When virtually welding, there are no flames or smoke. I think it is better with VR Simulation than the actual welding machines in the workshop*" (Participant 9, Apprentice, 0 years' experience).

This was the same for Participant 2, who indicated that the virtual reality welding simulator was suitable for a new learner or a novice to operate and that it could be used without any assistance from an instructor or trainer. The participant also noted that they were able to judge distances accurately and make calculated angle decisions.

> "*Training with the VR simulation was certainly easier. We used a lighter welding gun instead of a heavier one. Also, the room was air-conditioned and was ideal for training*" (Participant 8, Apprentice, 0 years' experience).

The marked difference of ease of use was confirmed by Participant 10, who stated that learning using XR was lighter to handle and manage, and this meant he did not experience the same level of anxiety associated with working with the traditional welding equipment.

> "*Yes, learning through VR training was simple. It is the easiest learning method. The anxiety of operating a welding machine is no longer an issue. So, yes, I believe it is simpler*" (Participant 10, Apprentice, 0 years' experience).

This was the same for Participant 2, who indicated that the virtual reality welding simulator was suitable for a new learner or a novice to operate and that it can be used without any assistance from an instructor or trainer.

"*Anyone can easily use the welding gun in the VR simulator. We do not need a trainer to help us. Once we can use the machine, things become easier. You will know how to measure the distance quickly and consider angles*" (Participant 2, Apprentice, 2 years' experience).

As can be seen in the findings, for the apprentices the XR welding session enabled the participants to learn and practice their welding techniques far easier and safer compared to the conventional welding setting. This was reinforced by the lack of anxiety experienced due to the removal of certain distractions like the associated noises and smells. Participant 5 summarised this perspective by stating that XR was overall beneficial in that the learner could make real progress in the training session with a high degree of efficiency compared to the traditional training setting, as the challenges of traditional welding equipment were removed.

"*I saw the progress we have made during our practical training. We were able to weld with greater efficiency. Many things have changed for the better. As a result, we can say that the VR training was beneficial to us*" (Participant 5, Apprentice, 0 years' experience).

5.4.4 Theme 6: XR cannot replace real-world training

While there was a consensus or agreement as to the benefits of XR, there were also some limitations identified by the apprentices. The next theme identified during the interviews was associated with whether XR could replace the traditional mode of training welding. The findings indicated that certain aspects of welding needed to be experienced first-hand, such as safety procedures. This was because XR was unable to recreate the entire experience of working in the actual welding environment. The themes that emerged from the second cycle are shown below in Table 5.6.

Themes	**Codes**
Theme 6: XR cannot replace real-world training	**Equipment**: A smaller area in XR compared to traditional
	Perception of the task: XR cannot accurately re-create the reality of the working environment
	Equipment: XR requires a background in computer

Table 5-6 Theme 6 and codes

Code 6.1: Equipment: Smaller area in XR compared to traditional

The limitations of XR included the area used was comparatively smaller compared to training in a traditional workshop environment. Participant 11, who had seven years of experience in welding, indicated that the smaller area used for XR was based on the manufacturer specifications rather than trying to replicate the real welding workshop.

> "*The working space available when using the VR machine is small and limited while the space available when using the real welding machine is unlimited*" (Participant 11, Apprentice, 7 years' experience).

This was reflected in the comments of another experienced learner, Participant 1, who added that he felt claustrophobic when working using the XR workspace.

> *"It felt to me that the working area via the VR and AR simulator is constricted and what if I want to train on welding a large work piece?"* (Participant 1, Apprentice, 4 years' experience).

Code 6.2: Perception of the task: XR cannot accurately re-create the reality of the working environment

As to the theme of XR or VR not being able to recreate the real welding environment, Participant 7, who had no experience in welding, stated that there was a sufficient weight difference between the cables used in the virtual reality welding simulator compared to the actual equipment, which meant that the training was not a true representation:

> "*The weight of the cable for the actual welding equipment is not the same as the weight for the VR simulator. Also, you should consider the safety measures while working the actual workshop*" (Participant 7, Apprentice, 0 years' experience).

Participant 5, who had never trained in welding before, drew on his experience of using the headwear in XR compared to the actual weight of the physical welding resource:

> "*Also, the helmet is lighter*" (Participant 5, Apprentice, 0 years' experience).

A new apprentice technician with no experience, Participant 7 compared the heating gun in XR which did not accurately produce the smoke generated from the real welding device, which was seen a limitation:

> "*The heating gun also produces smoke while welding. In a VR simulator, you are not exposed to this smoke*" (Participant 7, Apprentice, 0 years' experience).

Participant 5 also noted that even though XR provided a potential training welding solution, it could not be compared to the experience gained from traditional welding training.

> "*As you have already said, the VR teaches you how to handle the welding machine. But don't you think it costs a lot. Second and most importantly, if you practice more on VR, then it is much easier to move to learn on the traditional machine rather than directly starting with the traditional machine*" (Participant 5, Apprentice, 0 years' experience).

Therefore, although XR provided several benefits, it seems that the technology could not replace the realities of the traditional welding training experience. One new learner with no welding experience, Participant 5, noted that the real and XR methodologies do not always match or give the same experience. For example, virtual welding did not require the learner to wear protective equipment, and this was misleading to the learner's expectations. Furthermore, the XR simulation room was air-conditioned, while the real workshop was not.

> "*You should also consider the suit. You do not need to wear your suit during virtual welding; this can be dangerous in reality. Also, the room in VR simulation is air-conditioned*" (Participant 5, Apprentice, 0 years' experience).

Participant 2 reflected that during the XR session he had not been exposed to the real elements, such as the smell, sound, and fumes that are produced during welding.

> "*I can only say that we are not exposed to the hazard of the welding gas. The smell is bad*" (Participant 2, Apprentice, 2 years' experience).

From the perspective of Participant 2, it is possible to see that XR was still unable to reproduce or recreate the real welding setting. Participant 7 found that the XR technology was unable to create the heat, sparks, temperature, and smoke often generated. Since these risks

cannot be replicated, the safety measures, therefore, needed to be experienced in the real workshop environment.

> "*Compared to training on real welding machines. Virtual reality simulators did not achieve the same realism associated with welding training exercises for temperature, smoke and many other conditions, such as the welding helmet.* (Participant 5, Apprentice, 0 years' experience).

In summary, the training, when conducted using a welding simulator, was unable to reproduce the actual environment. This was because using real welding equipment enabled the learner to experience the sparks generated when welding, the heat produced when welding metal coupons, the vibrations, or the fumes and gases, or how the welding wire would get stuck when welding a coupon. The AR/VR simulator in comparison was unable to replicate this.

Code 6.3: Equipment: XR requires a familiarity of technology

Several learners with different experiences, like for example Participant 1, who had four years of welding experience, then Participant 11, who had seven years as a welder, along with Participant 5, with no experience, all emphasised that the use of XR required some form of basic computer skills:

> *"To be able to work with the simulator, you will need to have some background in computers"* (Participant 1, Apprentice, 4 years' experience).

Participant 11, added that extra guidance or instruction would be necessary for those who lacked the necessary computer experience:

> "*I believe that extra training would be required for people who are not familiar with using computers unlike the students that are tech savvy*" *"To be able to work with the simulator, you will need to have some background in computers"* (Participant 11, Apprentice, 7 years' experience).

For Participant 5, he found the experience easy as he was a player on PlayStation, therefore was comfortable with the XR equipment:

> "*VR is easy. But you have to have an idea with using PlayStation so that you can operate it with ease*" *"To be able to work with the simulator, you will need to have some background in computers"* (Participant 5, Apprentice, 0 years' experience).

From above it is possible to deduce that for XR to be effective, the learner needs to have some degree of experience of using technology. However, for most learners in this study, they were familiar with using technology and computers therefore did not require any additional time to start to use AR and VR when using the learning XR simulators.

5.4.5 Summary of Action Research Cycle

In addressing the three research questions: **Research question one**: what are the challenges and opportunities of implementing extended realities technologies in a vocational education setting in the UAE?, **Research question two**: how does the students learning experience change when implementing extended realities technology in vocational education in the UAE?, and **Research question three**: what is the instructor / trainers experience of implementing extended realities technology in vocational education in UAE?, the second cycle was focused on the application of XR technology to train apprentices to weld. The XR methodology enabled the individual to learn the fundamentals and basic skills for example becoming proficient in gaining eye and hand coordination attributes. Part of this could be linked to the absence of the PPE such as the welding helmet not being worn, a theme identified by AlMahmoud, Elkonaisi, Grivna and Abu-Aida (2020) which was a common complaint when wearing the conventional welding headwear.

Using a virtual environment, the challenges identified during the first cycle like the heat, the smells and the noises were not replicated or present during the second cycle. This enabled the learner to focus on their task in hand without any of the associated distractions, a theme identified by Jenson and Konraden (2018), Smith (2019) and Pottle (2019). However, as noted during the focus group, there was also the recognition that the real equipment could not be easily replicated and the workshop environment was still needed, as noted by Feier and Banciu (2021).

The apprentices also noted that the XR technology meant there was no need for the preparation of the resources, and the instruction did not need to occur on a one-to-one basis, therefore the entire cohort benefited from the instructor's presence. There was also the lack of physical resources needed to conduct the session, which often during the first cycle had to be replenished, leading to the session needing to be paused temporarily from time to time. However, there was a lack of authenticity as to the equipment and the absence of the real environment, which was important for the instructor, which was also identified by Seagull, Moses and Park (2008).

5.5 Action Research Cycle Three

Having completed the first and second cycles of the study, the researcher carried out the third phase, which was informed by the first two cycles. During the third cycle, the learners assembled in the welding workshop, but this time the training session used a hybrid teaching strategy of using both conventional welding equipment and VR and AR welding simulators. The third cycle was based on addressing the three research questions but using a hybrid mode of combining XR and the conventional mode of training apprentices to weld: **Research question one**: what are the challenges and opportunities of implementing extended realities technologies in a vocational education setting in the UAE?, **Research question two**: how does the students learning experience change when implementing extended realities technology in vocational education in the UAE?, and **Research question three**: what is the instructor / trainers experience of implementing extended realities technology in vocational education in UAE? informed by the learner's and trainers' feedback from the two cycles, the XR welding simulators were installed in the same welding workshop to provide the apprentices with a realistic environment. During this cycle, observations were taken down by the researcher, with a focus group interview conducted following the training session with the apprentices and one-to-one interviews with the instructors.

5.5.1 Theme 7: The preference of a hybrid training solution

The focus group identified that the combination training strategy, which included a hybrid of XR together with traditional welding equipment, was more beneficial than one strategy only. Part of the rationale was based on the perceived time and resource savings while also experiencing the real equipment. Table 5.7 below sets out the themes and their codes generated from cycle three's interviews.

Themes	Codes
Theme 7: Combined training is superior	**Perception of the training sequence**: Combining XR and traditional training have significant benefits
	Perception of the training sequence: Combined XR and traditional was beneficial than a single method
	Equipment: Combined training saves time and resources while all participants are engaged.

Table 5-7 Theme 7 and codes

Code 7.1: Perception of the training sequence: Combining XR and traditional training have significant benefits

The combination of XR and traditional welding was perceived as beneficial for the individual learner. A new apprentice who had no welding experience, Participant 5 a technician with no experience, noted that training in XR and then practising the same procedure using the actual equipment was very beneficial, as he noticed a positive difference in his skills level:

> "*I frankly benefited, and the matter affected me very much. Yes, you trained in VR in the first place. I got used to handling the welding gun and immediately went to real welding. I think I had much difference with me*" (Participant 5, Apprentice, 0 years' experience).

Participant 1, with 4 years' experience in welding, stated that this hybrid method provided him with the opportunity to see the angles of welding and his hand movements improved when using the simulator first and then put into practice these newly acquired skills in the real setting. Participant 1 also reflected on the experience by describing how using the simulator in conjunction with the XR enhanced their experience of using the equipment and allowed him to become more accustomed to the angles of use and gain the necessary skills due to the smoothness of training and the repetition of the task. These capabilities are not found when using traditional welding equipment.

> *"It gives me the opportunity or the. Yeah, allow you to work on my angles and. And steadiness and speed. In the. Virtual will already be in. It made it look like it helped*

me to correct on the move. Well, working. With the. With the equipment in the simulator, the real welding machine is more of well while we are doing that. I can see that. My angles, or I can? I could not adjust my angles. Faster or? In real-time. Then when I was working on the machine, I meant working on the simulator. The more usage I get with the simulator. Help me to adjust. With the real machine" (Participant 1, Apprentice, 4 years' experience).

An inexperienced apprentice, Participant 10, held the same perspective and stated that they could see how their proficiency increased. For Participant 10, he noted that he learnt how to properly handle the grip, the pace with which the hand goes to weld, and the distance and spacing between welds in XR. Then when applied in the real welding setting, he had the basic skills and ability to handle, grip, and master the hand movements required to use the real equipment.

"*I think the VR training with the traditional training has achieved very good results. I mean, the most thing you can notice. See how we were at the beginning and how we are now. Praise be to God. There is an improvement, but not 100%, in VR we learned how to properly handle the grip, the speed with which your hand moves to weld, and the distance. I mean, if the welding is sparking on you, you are too far. It is necessary to be closer but not too close*" (Participant 10, Apprentice, 0 years' experience).

Participant 1 added to Participant 10 perspective and stated that the XR methodology provided a less anxious environment to introduce the concept of welding, but then the learner experienced the realities of the working environment later when they were more confident.

"*Yes, overall, you can see that the students are becoming more and more comfortable. I mean more comfortable in the real-world environment. As they improve their skills from the augmented side and bring them over to the real side, you can see that they are more motivated and that there is an improvement. You can tell that the students were more motivated to show their skills. The instructor had a lot less stress in terms of preparation and cleaning coupons and house cleaning, for instance. No waste of material. Furthermore, at the same time, with all of this, the students are enhancing their skill as a welder*" (Participant 1, Apprentice, 4 years' experience).

Code 7.2: Perception of the training sequence: Combined XR and traditional was beneficial than a single method

Although indicated above, the use of both XR and traditional welding equipment was seen as more beneficial than using only a single mode of delivery. According to a learner with no welding experience, Participant 5, using virtual reality technology enabled him to learn about conventional equipment, such as a welding device, before experiencing it first-hand with the associated sounds and noises. Furthermore, the XR technology permitted him to hone his welding skills before applying it to the traditional workshop setting:

> "*It was even better that we came on the second day of working in VR, so that we are better. On the second day, I applied my VR welding learnt skills. Yes, the application is better. The idea is to get used to the routine by holding the handle when you use the VR, then go practice on the traditional welding machine. For me, I find it better*" (Participant 5, Apprentice, 0 years' experience).

The combination of training with the XR welding simulators and traditional welding equipment could improve both learner's progress and their ability to apply what they learnt in the real welding environment:

> *"I think the VR training and achievements have yielded outstanding results. I mean, the most you can notice. Look how we were in the beginning, how we are now"* (Participant 10, Apprentice, 0 years' experience).

For Participant 6, the integration of virtual reality and conventional welding equipment helped him to learn more about the operation in a practical context and enabled him to gain the necessary basic techniques.

> *"Of course, the benefit was very great in the workshop. We avoided the mistakes that were present, the fear that existed, for example, through the welding machine or the sparks that existed about it. We came back and learned some mistakes, the method of grip, the method of performance, something new for us, and the practical application was nearby the VR simulators"* (Participant 6, Apprentice, 0 years' experience).

Code 7.3: Equipment: Combined training saves time and resources while all participants are engaged.

Apart from enhancing the learner's skill levels, the combined training could potentially save time and resources when adopting a hybrid solution. Participant 7, who had no welding experience, highlighted that the third cycle enabled him to train on the XR resources to become more proficient in the fundamentals and then apply these new skills and techniques to traditional welding equipment, where he made fewer mistakes due to a higher level of engagement. There was also the impression that not only was saving time achieved, but it also meant the entire class was engaged.

> "*Saves time and material and provides faster education*" (Participant 7, Apprentice, 0 years' experience).

Participant 4 remarked that the combination of XR training with traditional welding saved the instructor's time. This may be because XR training could be used to learn the fundamental skills and then enable the learner to constantly practice, as the technology enabled a practical demonstration to be viewed, saving the instructor's time.

> "*It saves time even for the coach teaching the course, I mean, instead of what we took in theory. The VR welding machine shows the instructions*" (Participant 4, Apprentice, 3 years' experience).

This perspective was shared by an experienced learner, Participant 1, who emphasised the difficulty and time commitment associated with standard training:

> "*We are wasting too much time, and by the time we get on the machine, we are not familiar with it; we tend to be more nervous. The instructor was a bit busy getting us organized to do the training. In addition, before that, the material preparation required time and effort*" (Participant 1, Apprentice, 4 years' experience).

This was also observed by the researcher during the third cycle, that the learners used both methodologies simultaneously which provided them with the opportunity to practise on using the XR technology and the conventional resources. This strategy guaranteed that the learner had little downtime between welding classes. Furthermore, unlike in the first instruction cycle, where the learners were seen as being disengaged, here there was a more competitive

environment created since the XR resource can provide an immediate score after the learner has finished welding.

5.5.2 Theme 8: Improved skill development when combined training

From the third cycle, it was identified there was a perceived improvement in skill development when a hybrid approach to learning welding was adopted. Part of this was due to how the learners overcame the fear of welding, as the hybrid method enabled the trainees to gain more skills and confidence and the opportunity to evaluate their mistakes in real-time. Table 5.8 sets out the themes identified and generated from the findings.

Themes	Codes
Theme 8: Better skill development in combined training	**Perception of the task**: XR helps overcome the fear of welding, but in the same environment
	Perception of the task: Providing more confidence when transitioning from XR to traditional welding

Table 5-8 Theme 8 and codes

Code 8.1: Perception of the task: XR helps overcome the fear of welding but in the same environment

The results indicated that the participants were able to overcome their fear of welding, as the noises and the sparks were not generated in the XR environment. Then once competent, the learner could then be introduced to the real welding environment. Participant 6, who was inexperience in welding, illustrated this by stating that XR training enabled him to feel more confident about working with welding equipment because the use of virtual training assisted him in understanding the fundamental techniques, but as the XR equipment was located near to the actual equipment, the entire group was still exposed to the noise and smells of welding.

> "*Of course, the benefit of training with the combined training methods of VR and real welding machines was very great in the workshop. We avoided the mistakes and the fear that existed, for example, through the welding machine or the sparks about it. We came back and learned from mistakes, the method of grip, the method of performance, something new for us, and the practical application was close*" (Participant 6, Apprentice, 0 years' experience).

In comparison, a more knowledgeable learner, Participant 2, indicated that training with the combined training methods of XR and real welding resources enabled him to overcome his initial fears associated with the welding equipment, for example, the electric sparks generated and the other hazards, like the gases. However, the dual locality of the XR and actual welding resources made the overall learning experience real or authentic.

> "*I agree with the guys. I was afraid in the beginning from the electricity sound generated by the real welding machine, but after using the VR machine I feel that this fear is reduced, and it keeps reducing with each time I train using the VR equipment*". (Participant 2, Apprentice, 4 years' experience).

Code 8.2: Perception of the task: Providing more confidence when transitioning from VR to traditional welding

When the learners moved from XR technology to using the traditional welding equipment, there was a perceived higher level of confidence reported, including a good level of accuracy when welding. Participant 6 highlighted that when the training was conducted using XR, the technology enabled them to understand the techniques, which could immediately be practised and then applied using the actual welding resources.

> "*Because we all experienced the real welding and its dangers, and then we moved to virtual training. as what the guys said, VR enhanced the method of holding the welding gun, the speed, and then we applied the learnt skills again to the real machine in the same way, we benefited many things, and we achieved a very good percentage*" (Participant 6, Apprentice, 0 years' experience).

Participant 10, who had no prior experience in welding, also highlighted the benefits of combining training and the option to increase or develop their skill level before applying it to the actual working environment and how XR enabled them to concentrate and improve their basic techniques first.

> "*Of course, what we benefited from the workshop is the period in which we were trained. By default, we worked in a real work environment. I mean, you smell the smell of copper and iron while you hear the sound in the VR. We benefited and realised how we could improve ourselves*" (Participant 10, Apprentice, 0 years' experience).

For Participant 5, who also had no experience in welding, the XR training enabled him to become more familiar with the welding principles and gain a more practical understanding of the processes before being introduced to the inherent challenges and dangers of welding. This approach enabled him to overcome the existing anxieties and worries of operating the welding equipment for the first time. Participant 5 also noted that when working with XR, his skill levels tended to increase, also the level of quality of proficiency was enhanced, which then could be applied in the real welding environment.

> "*When you are working on VR, you improve your skill. You adjust the angle, speed, and so on. Then you go to work. Without the gap of time between going to the lab and the workshop, this is what is happening. My quality in welding is getting better. I am so sure*" (Participant 5, Apprentice, 0 years' experience).

Participant 1, who had four years of welding experience, indicated that training with a hybrid approach of XR and real welding equipment allowed him to learn more effectively and advance his welding proficiency. This perspective of the learner demonstrated an increase in ability, which could be linked directly to the usage of virtual reality training, as seen below:

> "*I enjoy working on the simulator. To me, it is more of a challenge. To get the beads right or to get a good picture when I am finished and look at that. And. Psychologically, I know that I am doing this and not wasting material. However, it stresses me out when I am doing it with the real machine that I have to get it right, or I am wasting time and material. So, I focus more on getting my beads right or my speed right when I do it with the real machine. Because I do not want it to go to waste*" (Participant 1, Apprentice, 4 years' experience).

From the findings, overall, the apprentices indicated that they were more focused on learning and acquiring the necessary skills which could be transferred to the actual workshop setting. The learners also saw that by learning through using XR, their competence level had increased together with the level of accomplishing the task.

5.5.3 Theme 9: Suggestions for further improvement

While combining training methods was beneficial, the learners also suggested certain improvements. To emerge from the focus group was the need for all XR training to be in the

workshop environment as the warm and humid conditions needed to be replicated, which is shown below in Table 5.9.

Themes	Codes
Theme 9: Suggestions for further improvement	**Perception of the task:** Need to try and emulate or replicate the real welding experience

Table 5-9 Theme 9 and codes

Code 9.1: Perception of the task: Need to try to emulate or replicate the real welding experience

The focus group findings indicated the need to conduct XR in the workshop so the humidity and heat could be experienced first-hand. A novice learner, Participant 8 stated that he still wanted to have the entire experience of the actual welding environment, for example the noise, the smell, and the heat, even during the XR training, as it helped him to understand the overall welding experience.

> "*It was an OK experience; of course, the VR at the beginning is better. For example, we set the VR in the place of the welding workshop. For example, the same student comes, the first one who achieves 90% in the VR score goes to real welding*" (Participant 8, Apprentice, 0 years' experience).

As seen above from the perspective of Participant 8, there was a need to try to emulate the real welding experience, such as providing the learners with the opportunity to feel not only the heat but the vibrations and the use of PPE. For Participant 5, despite the benefits of XR training resources for learning the basics of welding techniques, he wanted to gain hands-on experience with welding environment and resources.

> "*In short, instead of the VR being located in an air-conditioned place isolated from the workshop, you live the practical atmosphere in general from the sound of real welding to the sparks that came out when the VR machines are placed in the workshop, I mean, even when the instructor told us about the need to wear welding clothes, and I wore welding clothes and tried to weld with the VR simulator while wearing the real PPE, so it felt more like a real environment but in VR, and frankly, it makes a difference"* (Participant 5, Apprentice, 0 years' experience).

An experienced learner, Participant 1 also saw that the exposure to the heat, vibrations, and safety clothing / equipment was necessary and made it clear that, despite the benefits of XR training for learning the basics of welding, he still thought that hands-on experience of the welding environment and the resources was essential.

> "*We should utilize all the equipment available to make it more real. Instructors should enforce gloves and protective gear so the student can feel like he is in a real environment. The augmented reality needs some improvement in making it more real or feel more real in other dimensional situations where they might want to increase vibration with the torch or Sound vibration. Maybe heat simulators or something like that. Sound, vibration and other dimensions help create a real environment*" (Participant 1, Apprentice, 4 years' experience).

Reflecting above, it is essential to provide or replicate the real welding environment as closely as possible, which includes simulating heat and vibrations and the wearing of protective clothing, which was supported by Participant 1.

> "*The actual feeling you get with the torch is where the difference is. However, at the same time, it really helps you with the angles because augmented reality does not allow you to go off, cheat, or miss that angle without it showing up on the screen. So, it helps you to take that technique over to the shell*" (Participant 1, Apprentice, 4 years' experience).

5.5.4 Theme 10: Experiences of the Instructor

A total of six instructors were interviewed during the third cycle. The instructors were also asked about their experiences during the three phases. The themes which emerged from the three interviews sessions are presented below in Table 5.10.

Themes	Codes
Theme 10: Experiences of the Instructor	**Equipment**: No difficulty in training with combined XR and traditional
	Training experience: More control over the students
	Training experience: Seamless training experience using XR
	Equipment: Safety control is more efficient with XR
	Training experience: Better communication of errors in XR compared to traditional welding
	Training experience and equipment: Combined was better than single of delivery
	Training experience: Starting with XR is a good option
	Training experience: Real-time rectification of mistakes and errors
	Equipment: The need to emulate or replicate the real welding
	Training experience and equipment: Instructors can evaluate the performance of students post-training
	Equipment: XR (AR/VR) technology welding training devices offers mobility of the training services

Table 5-10 Theme 11 and codes

Code 10.1: Equipment: No difficulty in training with combined XR and traditional

The instructors were asked about their overall experiences of using XR technology and traditional welding resources, focusing on after the methodologies were integrated together. There was a consensus that the XR simulator enabled them to be an observer more than an instructor, and to assist, if need be, during the training session when the technology was being used. This was illustrated by an experienced welding instructor, Instructor 1:

> "*There was no difficulty training with the combination of the VR and AR and the traditional welding machines. I was comfortable training with a virtual reality simulator because it works as an observer on the other side with the students, meaning an observer and an assistant. And as an instructor, I was comfortable with it as it allowed me to focus with the students working with the real welding machines*" (Instructor 1, Welding, 10 years' experience).

Instructor 5, who had nine years of welding experience as an instructor, also noted that he preferred the VR training methods in comparison to traditional training since there was a lack of safety concerns which can lead to a better learning outcome. The apprentices, in his opinion, were more engaged with the materials, processes, techniques and the instruction without being concerned for their own safety. Instructor 5 also stated that he was able to teach various welding techniques more efficiently to the learner:

> "*I much prefer VR training (XR training) than traditional machine methods, where you train comfortably without fear of fire. While working in welding workshop requires more precautions and attention to safety. The VR has helped me teach the welding quickly*" (Instructor 5, Welding, 9 years' experience).

Code 10.2: Training experience: More control over the students

Overall, the instructors highlighted that they had more control over the apprentices, which was validated through the observations of the researcher. This control of the learners was based on the participation level of the trainees and how much time the apprentices were given to be exposed to learning how to weld.

> "*No difficulties because I could train and control the students more effectively…. In the third-cycle training, the risks of working in the workshop have been reduced to a minimum. Before, the control of dealing with flying sparks, flames, or pieces of iron made me anxious; I was with the students in real welding machines. While the other students with the VR simulators worked independently, the VR and AR simulators were safe from accidents.*" (Instructor 1, Welding, 10 years' experience).

Instructor 2, who had been teaching welding for 11 years, agreed with Instructor 1 and stated that during the practical training session:

> *"Also, there is a, a lot of, uh, time we are consuming at that one, the main difficulties we are facing about, uh, these all students are not easy to control in the one session. And one by one, they have to cut their pieces. And also, one by one, they have to learn, uh, according to parameters, but these students, but with the VR, it was very easy to control"* (Instructor 2, Welding, 11 years' experience).

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Instructor 3, who had ten years of teaching experience in welding, stated that with the assistance of AR and VR simulators, he was able to assist the apprentices more.

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> *"Additionally, the machines that's, and that's another benefit to where the using the AR machines, the machines would help the students on the spot right away. So, while they were, they are working, uh, and welding, um, a piece for example, or a coupon, the machine would give them directions as they go"* (Instructor 3, Welding, 10 years' experience).

Code 10.3: Training experience: Seamless training experience

The instructors also highlighted that using XR in conjunction with more traditional instruction led to a more streamlined learning experience for the learner. The trainers, like the apprentices also remarked that using the XR simulator and traditional resources within the same location provided a real workshop environment, which reduced the time needed to monitor apprentices and prepare practical training sessions, while also exposing the learners to the potential hazards and challenges of welding. Furthermore, using the XR simulator and traditional equipment together in the same setting reduced the likelihood of any accidents occurring. In addition, the instructors pointed out that they could prevent disruptions occurring to their training, such as running out of gas or practice tokens, by simply switching to XR technology only.

> "*Because with the help of the VR simulator and the traditional machines with the same settings as the real workshop environment to match the reality, it shortened much work on monitoring students and preparing for practical training for everyone. Not to mention that the third cycle training allows us to avoid the interruption to training such as running out of gas, and if it happened, I could easily switch to the virtual training simulator*" (Instructor 1, Welding, 10 years' experience).

This perspective was shared by another experienced instructor in welding, Instructor 2, who added that the apprentices in the XR environment perceived the setup as safe and therefore gained a higher level of confidence:

> "*Students in the VR, they are feeling the very good environment, same environment, especially they're getting confidence with the VR. Okay. This confidence leads them in, in future becomes a very good welder*" (Instructor 2, Welding, 11 years' experience).

Other trainers, such as Instructor 3, noticed that there was an increased level of trainee engagement and confidence in their overall experience due to a lack of safety concerns when using XR when being introduced for the first time to some fundamental welding concepts:

> "*From what I've noticed as an instructor in the classroom, the students were more engaged. They, uh, they did not have as much downtime and, uh, they overall, they were very happy about the experience*" (Instructor 3, Welding, 10 years' experience).

This perspective of Instructor 3 was mirrored by the experience of Instructor 4, who stated that training in XR had led the apprentices to gain a better experience in welding. Instructor 4 also noted that the technology seemed to provide the learner with a seamless means to learn the fundamentals.

> "*What I have noticed is, uh, it was very good experience with my students and as well as in my class, uh, every it, as we have immersed with the VR, uh, students were more engaged and they were learning better*" (Instructor 4, Welding, 10 years' experience).

Also, another welding instructor who has taught welding for ten years, Instructor 5, stated that they considered that virtual reality might be a 'game-changer' for welding education, as it permitted the learner to study at their own pace and apply what they see on the screen as to adjusting their distances, angles, and fix any mistakes. The traditional method, on the other hand, required the instructor to be physically present next to the learner during the whole learning process to guide the individual while not engaging with the rest of the group.

> "*I prefer to start using VR in welding teaching, where the student can learn more and gradually by applying the required right distances as shown on the screen, adjusting angles and correcting errors. But in traditional methods, the instructor makes great efforts by constantly being next to the trainee to adjust and correct his trainees' mistakes which takes too much time.* (Instructor 5, Welding, 9 years' experience).

Finally, Instructor 6, who has been teaching welding for more than 11 years, stated that virtual reality was potentially more cost and time effective compared to traditional welding

methods since there were no requirements for gas cylinders, welding wires, gloves, helmets, welding glasses, vests, or PPE. There was also no need for the preparation of materials or changing the gas cylinders during the session.

> "*The use of VR is economical and reduces costs because gas cylinders, welding wires, gloves, helmets, welding glasses and vests and PPE are not used in it. The student also feels safe from the possibility of fire or gas leakage etc. Students also find themselves in an atmosphere of competitive and motivational spirit to learn something new*" (Instructor 6, Welding, 11 years' experience).

Code 10.4: Equipment: Safety control is more efficient with XR

Following the implementation of XR to train welding, the instructors noted that the danger posed by using conventional welding equipment was significantly reduced. The risks posed by sparks, heat, and electricity were removed, as seen with the comments of Instructor 1, but the question is whether this is realistic for training apprentices to become future welders.

> "*Also, with the new third cycle training, the dangerous factors in the workshop were minimized. Students controlled dealing with flying sparks and flames or cutting iron, causing me insomnia when using the real welding machines because I had to be with them*" (Instructor 1, Welding, 10 years' experience).

Instructor 2, who had 11 years of teaching experience, also noted that safety concerns were removed when using the XR environment. This, for Instructor 2, meant that the learner could start to weld without fear of sparks and heat being generated. Some of the instructors could recall learners who when seeing the sparks on their shoes, gloves, or even on their flesh, caused them initial anxiety.

> *"VR is also good for the safety measures because safety in the traditional welding is different. Like students, sometimes they are scared about starting the welding. And if they see some, um, sparks, they have some time this, these sparks gone to their shoes, sometime their glove sometime on their body. So, from the beginning, they are scared, but in the VR, they can easily use all equipment with the short time. So, I think VR is the very best one for the beginning and for learning"* (Instructor 2, Welding, 11 years' experience).

Code 10.5: Training experience: better communication of errors in XR compared to traditional welding

All the instructors also mentioned that traditional training was less conducive compared to virtual reality when it came to communicating with the learners. An experienced welding instructor, Instructor 1 stated that during a traditional welding session, the apprentices were unable to clearly hear or follow the instructor's guidance, and that the learner often needed to stop the welding process to communicate with the trainer. However, this was not required when using XR as the instructor was able to speak with the learner easily.

> *"As for the students using VR training, communication was smother. I mean, while using the traditional machine, the student does not hear you when you talk to him, or if you want to guide him for something, why? Because he is afraid of the sparks, or he is afraid of the heat. I mean, he does not hear you. If you talk to him, he is far away, unlike the student who is in virtual reality, which if you talk to him; he talks to you while he is comfortable. In terms of communication with the students, it was hard with the traditional welding machines students.*" (Instructor 1, Welding, 10 years' experience).

Other instructors agreed with Instructor 1, including Instructor 2, who stated that communication with the learning in XR, VR and AR was easier.

> *"…communication with the VR was very easy and students focus, also, students did not need the instructor. Also. It was easy to see the progress of the students, easy to watch the students on the display, but in the real welding, really, it's very hard"* (Instructor 2, Welding, 11 years' experience).

This was supported by two experienced welding instructors, Instructor 3, and Instructor 4:

> *"…in terms of communication, the overall general, uh, thing that we noticed is that it was communication was much easier with the students than if, when using traditional only"* (Instructor 3, Welding, 10 years' experience).

"... the communication with them were very, very easy. And, uh, we were engaged in the start and first, uh, I showed them how to check the reserves and how to, to test the parameters and how to set the parameters and how to set the guides" (Instructor 4).

Code 10.6: Training experience and equipment: Combined was better than single mode of delivery

For the instructors, the use of a hybrid mode for training was found to be beneficial compared to a single method. During the third-cycle, virtual reality training was successful in meeting the training goals, as it kept all the apprentices interested, reduced the waiting time for the learner to practice, and meant that no one was left disengaged. The apprentices could also use the XR simulator to gain knowledge about the optimal welding angles, distances, and speeds. This resulted in the apprentices being able to maintain their level of interest and engagement before they practiced on the real equipment.

"*In the third cycle, we avoided the waiting time and waste materials for the first cycle and the cons of the virtual Reality only training cycle. With the third cycle, we effectively achieved our training objectives, engaged all the students, and eliminated the waiting time where the students had nothing to do until the machines were free. Additionally, we gain the benefits of a VR simulator in teaching the students and mastering the correct welding angles, and it teaches them the proper distance and speed when they weld. This makes students feel comfortable, motivated, and enthusiastic about the training. I noticed their welding skills improved and started to be more accurate, it enables you to learn welding 100%, and at the same time, it saves us from cutting iron and using wires. It saves the instructor time, especially when he will need to replace the gas cylinder when it runs out or other consumables materials. These things were draining the teacher's efforts and time to request and follow up on them because I had to order these, so this virtual reality technology made it easier for me and saved my time"* (Instructor 1, Welding, 10 years' experience).

Code 10.7: Training experience: Starting with XR is a good option

There was a consensus, like with the learners, that commencing with XR was beneficial, but needed to have also traditional welding included when training apprentices to weld. For Instructor 1, commencing with AR and VR simulators would enable the learner to migrate to traditional welding equipment more effectively. The instructor explained that the apprentices in the session firstly had the chance to develop their techniques and skills using XR. During

this time, Instructor 1 had observed that most of the learners performed better using XR, as there were minimal distractions. Also, he could watch and interact with all 12 apprentices, which was not feasible when using the real welding equipment. Finally, according to Instructor 1, who had 10 years expereince in teaching welding, the learners completed the welding tasks three to four times faster compared to in the traditional welding setting.

> "*Starting with the VR in the workshop allows the students to master the skills required, such as the right angle, speed and distance. After that, he can go to welding using the traditional machine. Nevertheless, the students improved their skills this time, and I noticed that most of them did very well. And can you imagine how could I do the training if I was only in it with the traditional machines and I have a large number of students, let us say ten students, for example! An entire day will not be enough for me to train them with the same efficiency as the combination of the two training aids. But by virtual Reality, you get every student to at least weld five or six pieces, meaning three times and four times as much as traditional welding*". (Instructor 1, Welding, 10 years' experience).

Another experienced trainer in welding, Instructor 2 highlighted that the use of AR and VR was a useful training tool as an introduction to welding:

> "*For the beginning, VR one is the essential, but in traditional some students, they are not good for beginning, especially when they have the problems when they are, they are they don't have any, uh, mathematics, like, especially diameter of the electrodes like this*" (Instructor 2, Welding, 11 years' experience).

Code 10.8: Training experience: Real-time rectification of mistakes and errors

The instructors also emphasised that virtual reality enabled them to provide immediate feedback to the learners. This real-time feedback to enable the learner to self-correct their errors, which enabled them to concentrate on areas of weakness as opposed to waiting for the guidance from the instructor:

> "*Whenever a particular mistake is made by the student in the traditional welding machine, the trainer immediately sends the student to the virtual reality simulator to practice and correct the mistake and then return to the real welding. This*

arrangement and training setting added value and advantage to welding training" (Instructor 1, Welding, 10 years' experience).

Instructor 2 highlighted that when the apprentices were using XR, they were not distracted by the associated safety concerns and the distractions of the real welding environment. This therefore enabled the learners to engage more and concentrate on the task, while the technology kept a score and evaluated the performance of the apprentice in real time:

"*Therefore, I was able to concentrate more on them and the students using VR, where basically on auto mode or autopilot mode, they were doing it all on their own. The machine was giving them the feedback. So, I only needed to give them, uh, some tips in the beginning*" (Instructor 2, Welding, 11 years' experience).

Code 10.9: Equipment: The need to emulate or replicate the real welding experience

For all the instructors like the apprentices, there was a need to conduct the training in the welding workshop environment. The instructors stated that the learners needed to get familiar with protective clothing, the noise level of using real welding equipment and the heat and sparks generated, therefore the technology should be in the same location:

"*The increase in realism in training, because in addition to protective clothing, there is the general atmosphere of working in the workshop, which from my point of view and my experience in training contributed a lot to making the student not feel that the virtual reality device is just a computer or a game because during the training in the workshop the student heard the sound of real welding machines beside him while training along with his colleagues and he feels the heat, gases and smells from the welding machines, in addition to that student is feeling that he is working such as real welding*" (Instructor 2, Welding, 10 years' experience).

Instructor 3, who has been teaching welding for 10 years, noted that the learner attained the fundamental skills through using XR, but then needed to be exposed and gain the real-life experience of using the welding equipment together with all the external distractions. Instructor 3 also observed that the learners did display some nervousness when experiencing the real workshop environment for the first time but was minimised with the addition of XR.

> "*What I noticed is that when they used the VR machine in the workshop, that fear was almost gone, it, it did not exist with them as much because they got used to it from, uh, the VR machine, which is a much safer way of obtaining this experience. Also, another thing is if you put the machine somewhere else and the traditional machines somewhere else, then the students would have to come like there would be some time off between using the VR machine and using the traditional machine. And that time off actually, uh, negatively impacts, uh, the results of the students, as I've noticed during the class, it's better if they're both in the same time, so they can immediately use the VR then immediately go and do traditional, this enhances their motor, uh, psychomotor skills. And, uh, basically makes it, uh, stronger with them so that they won't forget it as easy*" (Instructor 3, Welding, 10 years' experience).

For Instructor 4 it was necessary to house both the simulator and the real welding equipment in the same workshop. In doing this, for Instructor 4, this reduced the time between training on the simulator and using the actual welding equipment, but also enabled the apprentice to experience both training devices:

> "*We have to put both simulator and the traditional, uh, equipment in the same workshop. So, the both, if they are closer to the, like, if they are in the same workshop, that would be the best. And it will minimize the lag of, uh, learning because if we do the training of simulator on different place, and then we bring them through the workshop, so the environment will be different, and they might not feel that comfortable like welding while on simulator. And that would be difficult for them, for the students*" (Instructor 4, Welding, 10 years' experience).

This perspective of Instructor 4 was supported by Instructor 5, who had 10 years welding teaching experience, stated that there are several issues with utilizing only XR for welding training, as the sparks, heat, and actual tools, needed to be practiced on still. In the XR environment, welding flaws like holes or a stuck welding stick cannot be accurately recreated, therefore the learner would have to visit a real welding workshop or booth to gain the necessary hands-on training. Therefore, combining XR technology with a traditional welding setting would be beneficial:

"*The use of VR in welding is also insufficient on its own in training for a range of reasons. First, the VR does not reflect the realism of the welding process and its real atmosphere of sparks, heat and real welding components. The student must go to the real welding workshop (booth) for real welding training and recognize real errors that do not appear on the VR such as holes or real welding stuck stick. Traditional welding and VR are therefore indispensable together to complement each other*" (Instructor 5, Welding, 9 years' experience).

Instructor 6 who is training welders for 10 years also shared the opinion related to the need that the individual had to experience real welding equipment first-hand and not virtually, as the learner needed to learn about recalibrating their devices before their welding task:

"*The VR also lacks the realism which found inside the real welding workshop, since the results appear only visible and intangible on the displayed screen. VR also lacks the principle of calibration in which students cannot calibrate the equipment to start work*" (Instructor 6, Welding, 10 years' experience).

Code 10.10: Training experience and equipment: The instructor can evaluate the performance of students post-training

The instructors also considered that XR had the benefit of enabling them to monitor each learner's progression and errors while using the XR simulator. There was also the XR database, which documented and tracked the learner's progression and could be accessed later by the apprentice, whereas with the traditional mode of learning, the learner could hide their errors, but XR captured mistakes and errors.

"*One of the advantages of the virtual reality simulator enables the teacher to follow up on each student and how much time he has spent training and what his mistakes are through the database feature for trainees in preparing the virtual reality. At the same time, in the traditional welding machines, the student can destroy his piece of work and throw it without being observed by the instructor, which does not let me know which student needs more focus and which part exactly. Is it speed? Or angle? Or even the distance? This advantage allowed the Virtual Reality and Augmented Reality simulator to help the instructor monitor and supervise students. Also, with the help of virtual reality and machines, we can train up to 20 students simultaneously*

instead of ten. The instructor can constantly switch between the two groups and with the same training goal" (Instructor 1, Welding, 10 years' experience).

In comparing the two modes of learning, Instructor 5 with 9 years of experience stated that unlike conventional training of welding, where the apprentice often only gets one opportunity to practice, with XR, the learner can repeat and practice their skills:

"*At the same time, I benefited from the VR using the data recorded in it for students' attempts. It helped me greatly in making a file for each student and monitoring his results and reports on the evolution of his skills. In welding using VR, the student may make 5 or 7 attempts contrasted with one attempt at traditional (applied) welding*" (Instructor 5, Welding, 9 years' experience).

This was also identified by Instructor 6 who highlighted that the use of XR enabled the trainee to rectify errors and then provided the trainer with information on the apprentice's previous attempts and outcomes:

"*It helps correct mistakes for students and provides me with data on students' history of attempts and corrections. This helped to prepare a file on the results of each student's attempts*" (Instructor 6, Welding, 11 years' experience).

Code 10.11: Equipment: XR (AR/VR) technology welding training devices offers mobility of the training services

In preparing for the third session, the logistics of moving the XR equipment into the welding environment proved to be relatively easy to organize. An experienced instructor in welding, Instructor 1 mentioned that the process of transferring virtual and augmented reality simulators was easy because of its light weight and the availability of special prepared boxes took minimal time to organize.

"In the third action cycle and before the combined training methods I managed smoothly to move the A/VR welding simulators from the VR lab to the welding workshop, also when i set up the AR/VR welding simulator again it was very easy and saved the instructor time" (Instructor 1, Welding, 10 years' experience).

Instructor 4 agreed with Instructor 1 and stated that there were other possibilities that can be exploited in the future where these simulators and virtual reality techniques could be transferred to train welding apprentices in remote learning environments:

> *"I didn't find moving the AR and VR simulators difficult and with the package it was easy to pack and move it anywhere, this will help training welders in remote places* (Instructor 4, Welding, 10 years' experience).

This usage of XR in different localities was also highlighted by Instructor 3, who had 10 years of welding instructions. For Instructor 10, he found the process of moving and transferring virtual reality simulators much easier than expected, and unlike transferring traditional welding equipment, gas cylinders and welding elements, the XR technology was much easier to set up.

> *"…with the AR simulator it was straight forward to pack the simulator in the bag and move the simulator to other location, unlike the real welding machines which is heavy and required more efforts and special equipment to move them and also needs more than one instructor to do the same task"* (Instructor 1, Welding, 10 years' experience).

For Instructor 5 he agreed with Instructor 1, with 10 years' experience, and Instructor 3, who had 9 years' experience, as to the ease of being able to transfer the AR / VR welding simulators, and likened the process as to moving a desktop computer:

> *"Moving the VR simulator was very easy, and it was like moving a desktop computer from one office to other and the good thing is the special package helped the instructor to pack the VR and move it anywhere without any issues"* (Instructor 5, Welding, 9 years' experience).

The researcher also observed how easily it was to relocate the VR / AR equipment and the usage of the special box used for the transportation. This was encapsulated by Instructor 3 who stated the XR welding simulators were not heavy and the movement of the technology to the welding workshop was easy, he just plugged the cable of the simulator into the power, and he was then able to train the apprentices:

"The Virtual reality welding simulator weight was not heavy, and we moved to the allied trades workshop very easily and when we just plugged the simulator to the electricity cable and we managed to train the students again". (Instructor 3, Welding, 10 years' experience).

5.5.5 Summary of the Third Cycle

The final cycle of the study addressed the three research questions, but through a hybrid mode. The hybrid approach provided a series of benefits from both the learner and the instructor perspectives. The findings indicated that some of the identified limitations of each of the other methodologies could be addressed or strengthened by the other. For example, where the apprentice using XR technology, the learners were able to practice the basic skills without the distractions of the real environment, for example the heat, smell, and the sound of the electricity, which can be off-putting. However, in gaining these new acquired skills via XR technology, the equipment was not seen as replicating the actual resources, which were skills needed to be experienced when learning how to weld. The third cycle recognized however that the authentic nature of XR was still lacking, which led to both the apprentice and the instructor to highlight the need for the real environment, such as the heat of the working environment and the associated safety issues to be present when training welding. This finding supports the earlier research of Seagull, Moses, and Park (2008) who noted the importance of the real vocational environment.

The instructors saw the benefits of XR as to improved communication with the apprentices, which could be done in real-time, which enabled the learner to rectify mistakes as they occurred. This could not easily happen during the conventional training programme, due to the external environment and the wearing of the PPE. Often the wearing of the helmet also impeded the learner's vision. However, XR technology could not replicate the actual welding process, therefore the conventional welding process was needed to be intregrated into the training session.

5.6 Outcome of the three cycles generated from the XR technology

To understand the three cycles as to the changes of the learners' skill acquisition, the study also drew on the apprentice's performance to support the qualititive perspectives of the trainees and the instructors. To achieve this, during the first cycle, the learners were given two days of instructions followed by a training course in welding in GMAW, before taking their first welding test. The first cycle comprised of a traditional teaching approach and trained the

learners to use the welding equipment to perform a welding task. At the end of the session, although most the apprentices' grades were satisfactory, both the instructors, and most of the learners perceived that the overall welding ability as to angles, speed, and hand distance still needed to be developed. This was captured in the perspective of Participant 4:

> *"I have real difficulty in doing welding in a straight line as I feel that even if I move my hand a little bit, it will go wrong. Managing my hand for this is very hard as my hands shake a lot"* (Participant 4, Apprentice, 3 years' experience).

During the second cycle of using only XR, the learners received a brief training session followed by a refresher course on the basic welding techniques using the XR technology. With the AR/VR simulators, the learner's grades were overall satisfactory. However, there was still areas for improvement. Most of the learners still lacked the required welding skills including in angles, speed, and hand distance. While most of the performance was satisfactory, it was determined that the learners still needed several more lessons before they could advance to the next level of welding education. From the interviews, the apprentices highlighted the need for further practice, like with Participant 6 and Participant 9. For Participant 6 it was about more practice to stabilize their hand:

> "*We need time to stabilize the hand and stop the shaking or trembling. This is the most important thing*" (Participant 6, Apprentice, 0 years' experience).

While for Participant 9, it was more to do with repeating the same task:

> "*Of course, in the beginning, it is impossible for anything new to be easy. It must be difficult. This may be a little difficult at [in the beginning] first, but it will be easier with repetition. But it was difficult in the beginning*" (Participant 9, Apprentice, 0 years' experience).

The last cycle, the third stage, the learners again received a few days of instruction followed by a review before their welding examination. The third cycle comprised of the learners using conventional and augmented reality equipment, followed by an examination utilising traditional welding equipment. The results of the learners are shown below in Table 5.11.

Name and number	Age	Cycle 1 Score (Traditional welding %)	Cycle 2 Score (VR/AR %)	Cycle 3 (Traditional + AR/VR%)
Participant 1	58	72	64	86
Participant 2	32	88	76	92
Participant 3	47	88	76	80
Participant 4	53	85	73	90
Participant 5	44	75	66	84
Participant 6	47	84	76	89
Participant 7	32	80	69	87
Participant 8	22	84	76	92
Participant 9	30	86	72	90
Participant 10	30	89	78	94
Participant 11	25	83	76	90
Participant 12	24	70	77	85
Overall average	**37**	**82**	**73**	**88**

Table 5-11 Scores of the students across the three cycles

In analysing the accuracy of the learners, data was gathered from the instructors as to the outcome of the apprentices' overall performance at the end of the session, which is illustrated in Table 5.11 which shows the reported accuracy during the three cycles. As can be seen in Table 5.11, interestingly the first cycle which involved the traditional training session of learning how to weld using the actual equipment, the average level of accuracy was reported to be 82% when performing the required task. This contrasted with the second cycle which involved the XR technology, which produced a reported lower level of accuracy of 73%, where the apprentices were instructed only through using the simulated virtual equipment. When the methodologies were combined, the level of accuracy was reported to be around 88%, which is significantly higher than if the apprentices used only XR technology. When compared to the using the traditional mode of learning, the level of accuracy of the apprentices using the hybrid model was slightly higher, indicating the importance of retaining the traditional usage of welding equipment. In analysing the data further, there was also no direct connection between age and the level of accuracy for the usage of the traditional, virtual XR or hybrid modes of learning, indicating a potential compatibility of using a hybrid approach, while challenging the perspective that XR technology can replace traditional modes of learning when training apprentices to learn to weld.

The performance of welding scores in the three phases suggests that the younger students performed better than older learners when using extended reality, as seen in cycle 2. In contrast the older students performed better in the first cycle of using conventional welding equipment. This difference in performance could be related to the learner's familiarity and adaptability, as the younger learners were used to new technologies and digital tools compared to older learners. As a result, the younger apprentices might find it easier to understand and utilise XR to learn how to weld, leading to better performance. Furthermore, different age groups may have varying learning preferences, which means that a hybrid blend of approaches are needed.

From the findings of the study, XR in welding offers a dynamic and immersive learning experience, which can engage and motivate younger students into the learning experience. Also, conventional welding equipment requires a high level of hand-eye coordination, precision, and physical dexterity. In this study the older learners may have developed some technical skills over time through their experience with traditional tools and equipment. Therefore, these learners might exhibit better performance when using these physical tools compared to younger students who are new to a vocational and welding environment.

From the interviews, the outcome was more positive, like with Instructor 1, who highlighted the benefits and the sequence of using XR first:

> *Starting with the VR in the workshop allows the students to master the skills required, such as the right angle, speed and distance. After that, he can go to welding using the traditional machine (Instructor 1).*

In contrast, for the learners, there was an acknowledgement as to their improved acquired skills and proficiencies. This can be seen in the comments of Participant 8:

> *It was an OK experience; of course, the VR at the beginning is better. For example, we set the VR in the place of the welding workshop. For example, the same student comes, the first one who achieves 90% in the VR score goes to real welding*" (Participant 8).

This perspective of Participant 8 was also captured in Table 5.11, which illustrates interestingly that in cycle one, the scores indicated that the learners irrespective of the environment which was seen as being disruptive had a better learning outcome compared to the XR technology. The XR session scores indicated that the outcomes and the accuracy

levels were not rated as high as originally perceived by the apprentices, but this discrepancy could be related to the XR headwear being worn and possibly due to the over-confidence of the learner. However, with the hybrid approach, the overall scores were clearly positive.

5.7 Chapter Summary

The study was based on investigating the experiences of learners and instructors using XR, virtual and augmented reality technologies in an UAE welding training course. In line with the study's aim, an action research approach was adopted, comprising of three iterative cycles. The first cycle involved the learners being trained using the traditional technique of spot welding with the tutor demonstrating the skill before enabling the apprentice with close instruction, to practice themselves on a one-to-one basis. The second research cycle involved the training being carried out using XR only. In the third cycle of the final iteration, the learners underwent XR training first, followed by the session using a traditional training strategy. During each of these cycles, the researcher conducted a focus group with the learners, interviewing the instructors on a one-to-one basis and through personal observations.

There was a prevailing view that traditional training has substantial challenges such as being time consuming, needing resources, little engagement with the tutor or the opportunity to practice, and the initial fear of sparks and electricity. These challenges were mitigated with the usage of XR technology, however, with a XR approach, the apprentice was missing the authentic real welding experience. This was because XR cannot emulate the real-world experience, and while it certainly can help the apprentices fine-tune their skills and make the learning experience more engaging, it cannot be used as the only resource or learning methodology. To address this, the combination of both XR and traditional training proved to be highly beneficial in allowing the learners not only to overcome their fear of the welding environment like the generation of sparks and electricity, but also helped them fine-tune their skills and gain more confidence in using the welding equipment. The apprentice's performance was also measured, and it was evident that their performance improved significantly with combined training compared to using a single method.

Chapter Six
Discussion

6.1 Introduction

This Chapter will present the discussion of the findings generated from the qualitative study which was aimed at investigating the potential benefits and challenges associated with implementing extended reality technologies in a technical and vocational educational setting in the UAE to train apprentices to weld. In line with this aim, the following research objectives were addressed:

Objective One: To critically analyse and evaluate associated challenges and opportunities of implementing extended reality technologies in vocational education in the UAE.

Objective Two: To critically evaluate the student's learning experience when implementing extended reality technologies in vocational education in the UAE.

Objective Three: To critically evaluate the instructor training experience when implementing extended reality technologies in vocational education in the UAE.

Objective Four: To give a recommendation on overcoming the challenges faced in exploiting the opportunities of extended reality technologies in vocational education in the UAE.

In line with the above aim and objectives, the study adopted a qualitative method to conduct an intervention approach using an action research strategy which involved a total of three cycles during a welding training course. The research findings from the interviews generated from the three action cycles were presented in the previous chapter. In this Chapter, the purpose is to critically interpret and discuss the outcomes of the study in relation to the existing knowledge, as presented in Chapter Two and Chapter Three of the literature reviews. To present this critical discussion, the Chapter will address the study's research questions, which were developed to achieve the above research objectives:

Research Question One: what are the challenges and opportunities of implementing extended realities technologies in a vocational education setting in the UAE?

Research Question Two: how does the students learning experience change when implementing extended realities technology in vocational education in the UAE?

Research Question Three: what is the instructor / trainers experience of implementing extended realities technology in vocational education in UAE?

6.2 Key findings of the study

In this section of the Chapter, the key findings of the study will be presented, whereby addressing the research questions above while providing a critical insight into how the utilisation of XR technology to train welding can potentially improve the training of apprentices to weld in a vocational training setting. The overarching finding of this study is that the use of XR technology in welding training can potentially enhance the vocational learning experience. This technology can help both the trainee and instructor to overcome and mitigate some of the challenges associated with traditional training of apprentices as to how to weld. The utilisation of XR technology can reduce the time required for the apprentice or trainee to gain the necessary skills while lowering the training cost and reducing the number of materials required during a typical session. The study's findings indicated that the XR welding equipment did assist the trainees to gain greater confidence when operating real welding equipment due to their improved psychomotor skills while eliminating the initial perceived fears and anxiety when encountering the fundamentals of welding for the first time, as they had mastered the basic skills before they encountered the actual welding equipment. This finding supports the earlier work of Du Wulf (2007) and later by Boyles (2017), who indicated that apprentices learning how to weld needed time and continuous feedback to improve their psychomotor skills, like eye and hand coordination.

From the perspective of this study, the findings support the notion that a mixed approach where the use of traditional welding equipment and XR welding training methodology can potentially improve the welding training experience. However, while the XR welding simulators can benefit and enhance welding training, instead this study contends that this technology cannot completely replace traditional welding training sessions, which challenges Smith (2019), Pottle (2019) and Lavrentieva et al. (2020), contention that XR can substitute the conventional methods to train vocational welding. This study argues that a combined training approach can provide the trainee with a duality of engagement and skill development in learning to weld. Furthermore, the usage of XR welding training devices had a perceived positive impact on the instructor and their role. Found in this study, was that the inclusion of XR technology enabled the tutors to run a more inclusive training experience for all learners, while also enabling them to monitor the apprentices progress in real-time, which can be challenging when training using conventional vocational approaches.

6.3 The benefits of the traditional welding training

As indicated in the previous chapter, at the beginning of the study, the first cycle of the research project involved using traditional welding equipment for training, offered the learner and instructor many potential benefits in terms of acquiring the necessary professional skills. The traditional welding equipment permitted the learners to be trained on how to efficiently use and handle real welding equipment and associated components such as a torch, wire feeder, the gas cylinder, gas regulator and the ground cable. With this real hands-on experience, the apprentice was able to use traditional welding equipment efficiently when practising welding tasks, including selecting and using a certain thickness of wire, which is very important and necessary for welding operations, a theme earlier explored by Kamberg (2019), who noted the invaluable experience that handling the actual resources provides. As explained in Chapter Three, training in conventional welding equipment can expose the learner to the actual welding environment and therefore increase their knowledge of how to handle the welding equipment, including troubleshooting when there are potential calibration or safety issues. The trainees in this study also gain real-life experience on how heavy the materials can be and how the welding resources felt, which assists, develops, and builds their psychomotor skills, as highlighted by the studies of Okimoto, Okimoto and Goldbach (2015), Stone, McLaurin Zhong and Watts (2013) and Papakostas, Troussas, Krouska and Sgouropoulou (2022). In building on these earlier studies, this study also provided an observational aspect together with a comparative component as to how effective conventional welding training can be in this vocational educational setting. Furthermore, while these studies of Okimoto et al. (2015), Stone et al. (2013) and Papakostas et al. (2022), presented an overly positive view of integrating XR into welding education, this study does challenge this portrayal. Instead, this study contends that XR can supplement rather than replace conventional training of welding practices. Linked to this, this study also found that training with traditional welding equipment was beneficial for the learner, as it enabled the apprentice to interact with the real materials, thereby helping the apprentice to engage physically with the welding experience. However, on reflection, this identified benefit may have been influenced by the fact that it was the first experience for these learners as to welding training, as this grouping had not had any previous contact with welding and the equipment or materials used. This premise challenges the work of Moro et al. (2021), and Nasir et al. (2011) who argued that it was critical for the learner to have hands-on experience from the outset to then be proficient or competent in the work-related activities. This study contends

that using XR technology can enable the learner to gain the necessary fundamental skills, before then engaging with the actual equipment.

To emerge from the findings was that from the learners' perspective that a traditional learning setting enabled safety training to be effectively understood, particularly if conventional welding equipment was used as a demonstrator. Furthermore, the interactive element of real welding equipment and resources was beneficial as it enabled the apprentices to experience and develop real hands-on proficiencies by completing an actual welding project, such as welding coupons, while also spending time ensuring that their activities were conducted safely. As seen in the findings, this usage of conventional welding equipment in a training session can expose the learner to different welding hazards, which can occur if safety standards are not followed. The study found that XR technology was unable to reproduce possible hazards and accidents if the equipment was incorrectly used or due to the machinery not being calibrated correctly. As reported in the findings, the trainees were also exposed to the real dangers such as sparks generated during the welding process, exposure to gases, radiation from ultraviolet and infrared, together with the heat generated, which provided a reinforcement for the apprentices to take safety seriously, which concurs with the findings of Golbabaei and Khadem (2015). However, while Golbabaei and Khadem's (2015) study outlined that traditional training methods in welding can reduce confidence, this study contends that the use of XR strategically as a supplement, can enhance the learning experience. The study also found that using real equipment did require constant progression and reinforcement of those skills and knowledge gained, therefore there was a need for the learner to be constantly practicing but this could be problematic due to the reported and observed wait times. This 'wait time' often occurred as the instructor needed to train the individual on a one-to-one basis due to the associated risks of using traditional welding equipment and workshop hazards. This identified limitation of welding in a traditional learning methodology mirrored the studies of Chakradhar et al. (2022), who reported that it took longer to train the learner in the required welding skills compared to the use of VR and AR technologies. To address this finding and reflecting the work of Chakradhar et al. (2022), this study contends that the use of XR technology should occur as the first step where the learner is shown the basic techniques, before then being exposed to the real welding environment after gaining or acquiring the fundamentals skills, but still needs to practice on real welding equipment.

6.4 Challenges of traditional welding training

This section will focus on the challenges associated with training apprentices to use traditional welding equipment. The findings of the study indicated that the learner when faced with multiple new challenges when being trained how to weld with traditional welding equipment, that the learning experience was potentially compromised. For the learners, the welding workshop was poorly ventilated, which caused substantial discomfort for them. This theme of poor ventilation was often due to the use of CO2 gases used for welding, which combined with the creation of sparks, ultraviolet radiation, and high heat, can make the learning environment hazardous and not conducive for both the learner and the instructor. The study also identified that the learner felt unengaged in welding training because of the harsh work environment of the humidity, gases and heat produced by the welding equipment throughout the practical training session. This lack of appropriate ventilation was a significant challenge that the apprentices experienced during their practical training sessions. This was also compounded by the necessity to use personal protective equipment (PPE) which needed to be used in a welding environment. These identified limitations were aligned to the earlier work of Lombardi et al. (2005, 2009) who observed that often the PPE and in particular the wearing of the welding helmet for eye protection was often a limitation or impediment for the learner to clearly see the welding activity.

As noted by Kim and Lee (2020), welding is a physically demanding, strenuous, and heat-related occupation, which involves sparks being generated together with ultraviolet and infrared light being produced, therefore PPE is needed, but this can be a discomfort and restrictive to the trainee. As seen in the findings, the usage of PPE was seen as being heavy, restrictive, and making breathing hard, which could potentially reduce the quality of learning in the training sessions. However, it should be noted and recognised that welding in reality, is often conducted in poor and harsh working conditions, which presents challenges in the actual welding workshop, but as identified in this study, exposing the learner to reality can enable the apprentice to practice their skills in a real welding setting, something that VR and AR technologies cannot re-produce.

In developing the theme further as to the restriction of PPE, the findings of the study found that the learners often reported a certain amount of lack of confidence when they first tried out the welding process and equipment. This lack of confidence and potential safety fears could result in the learning process being hindered. This was also linked to how the welding process was performed using the necessary PPE, as all trainees needed to wear helmets that

had low visibility until the welding process began, a theme identified by Lombardi et al. (2005, 2009). The low visibility when wearing helmets was identified as a significant challenge when welding by the apprentices. Even when the shading level was the lowest possible, the learners could not see the actual weld as it was being performed. This finding of poor visibility due to the PPE was highlighted and supported by AlMahmoud, Elkonaisi, Grivna, and Abu-Zida (2020) who stated that PPE was a common complaint amongst learners, instructors, and qualified welders, due to the poor vision through PPE lenses. This study also identified that poor visibility apart from being challenging to see, it also led to the learner not to be as accurate or precise in their welding activities.

To address this, this study looked at whether PPE could be introduced later in the training of welding. This led to the use of XR, or AR/VR welding technologies that could enable the trainee to learn how to perform certain welding tasks, although virtual, and not need to use the restrictive PPE. This lack of PPE enabled the learner to conduct the welding process, particularly at the beginning, as to how to weld, in real time, with clear visibility. Once familiar with the process, the learner could then move to the traditional welding equipment and become familiar with PPE, which, although partially impairing the learner's vision, the fundamental skills associated with welding acquired. The study results align with the earlier work of Lavrentieva et al. (2021) by concurring that the implementation of XR welding simulators in vocational training can enable the learner to master welding skills faster. However, the findings of this study do contradict Wells and Miller (2020), who stated that training with the help of XR welding devices did not necessarily benefit the learner's experience, and the use of VR technology did not indicate a significant impact on the apprentice's performance. The findings of this study instead contend that through the adoption of XR technology can enhance the learner but needs to be conducted in a hybrid methodology of conventional and XR learning resources.

The findings of this study identified that in a traditional welding setting, the learner needed to gain strength, stable hand movement and welding control quickly, which was identified as a challenge for the learner to gain initially when using traditional welding equipment only. In the studies by Whitney and Stephens (2014) and Chan et al. (2022), both independently identified the challenges associated with welding training particularly as to the time available for the learner to practice their skills. This can be compounded if the learners are in groups, as often the training needs to be conducted on a one-to-one basis. The learners in this study indicated that there was a time constraint involved in training, particularly as to gaining the level of expertise in maintaining hand stability proficiency needed to perform the welding

task and meet the required accuracy rates. This necessity for gaining this level of hand stability meant that the learner needed to have time to practice during the training session to achieve this competency, and it can also result in the wastage of materials. In a traditional setting, this hand stability can be impeded by flying sparks being generated during the practical session, which can be off-putting for the apprentice. Several of the learners reported that the sparks, heat, and noise generated were initially unexpected and sometimes put the learner off, which meant they were not focused on gaining the necessary psychomotor skills. However, as revealed in this study, this initial fear tended to occur at the early stages of the welding training session, then as the apprentice progressed and gained more confidence and skills, the apprentice became more familiar with the presence of external factors. The findings were consistent and supported the earlier work of Agrawal and Pillai (2020), who stated that traditional welding presented several challenges in the form of safety risks which can impede on the learner gaining the fundamental skills such as hand control and stability, but it is necessary for the learner to become familiar with them before working in a real welding environment. While this study agrees with Agrawal and Pillai (2020), the findings also extend the research providing a hybrid solution to training apprentice welders in a vocational setting, through using several recommendations that can help the learner become more acquainted with the risks and challenges while gaining the necessary psychomotor skills by using XR technology combined with more traditional methodologies.

Using a real training environment to conduct the study, where welding training was taught, enabled this research project to focus on the reality of vocational education. The setting involved training the apprentices using only a few pieces of welding equipment, which could be operated by one trainee at a time due to the limited number of instructors assigned to the course. As a result, the instructor was unable to train and observe all the learners using the equipment once. As a result, the instructor needed to divide the apprentices into pairs and train each group one-by-one, while the other groups waited. While the apprentices waited for their turn to practice, there was reportedly a high level of disengagement and a loss of motivation amongst the learners. To address and further expand on the work of Papakostas et al. (2022), whose study while indicating that learning how to weld in a traditional setting can have a high resource cost, which this study agrees with, the original study did neglect to resolve the potential long waiting time for the individuals to practice and perform their welding task, which this study contends is possible through a hybrid solution.

To emerge from the findings was the importance of calibrating the welding equipment during the workshop training session to demonstrate to the learners, which can be a challenge, as this

procedure is initially only performed by the instructor and none of the students were involved in calibration. The observations of the study found, that while the calibration was being carried out, the learner was unable to perform any welding tasks or engage in further practical activities, therefore became disengaged. Part of the reason for the instructor being the only individual permitted or authorised initially to calibrate the equipment is that the process needs to be accurately completed, as the safety features are dependent on accurate calibration. Furthermore, the calibration process of the welding equipment enabled the learners to gain experience in welding to the prescribed level of quality needed for industry (Troussau et al., 2022). Although the calibration process commenced before the class began, the equipment often needed to be readjusted as the session progressed. This delay can lead to training being stopped and time being lost, hindering, or slowing down the learning process, an interesting theme that, to date, had yet to be investigated from a welding perspective. The outcome of this study was that the trainees began to become demotivated and lost interest in the learning activity due to the less involvement, which resulted in the instructor needing to repeat the previous task again.

In summary, this study has found that during a normal welding practice session, which incorporated actual welding training equipment, there were several limitations for training using the conventional equipment and the associated environment. For example, the poor ventilation in the workshop made it more difficult to successfully perform hands-on training, including the learner gaining the correct level of psychomotor skill proficiency. It was reported that the PPE was seen as being heavy, which provided poor visibility and made breathing hard, which could potentially reduce the quality of learning in the training session. Training welding apprentices requires a high level of hand-eye coordination, and because the welding environment, even for learning the essential skills, are hazardous and accident-prone due to the presence of intense arc light, sparks, gases, and ultraviolet rays, which can present a safety hazard, therefore PPE needs to be worn, as noted and acknowledged by AlMahmoud, Elkonaisi, Grivna, and Abu-Zida (2020). There was also the acknowledgement that material preparation for traditional welding training needed time for the instructor to pre-prepare and then replenished during the session, like for example, the welding coupons, the calibration of the equipment, and ensuring all resources were working, with an ample supply of welding gas such as CO2. These activities can be a distraction for the instructor from actually teaching welding and can also result in limited motivation and engagement from the apprentices if the session is constantly stopping. Reflecting this there are clearly substantial challenges that can occur when teaching welding through traditional means. However, it should be acknowledged

that training with traditional welding equipment cannot be fully replaced, but more that there are several teaching aid opportunities to consider when training apprentices to weld, such as the use of XR welding simulators.

6.5 Challenges and opportunities of implementing AR/VR technologies in welding education in the UAE

As presented above, there are several benefits and challenges associated with learning how to weld through traditional training methods. In investigating the traditional methods of training an apprentice in welding, this research project also included the use of AR and VR technologies in the second cycle of the research approach. The findings revealed that XR technologies in welding training presented some interesting benefits when used in a vocational training setting. Firstly, the findings of the study indicated that XR technologies could help apprentices develop better skills, improve their confidence, practice essential hand coordination and movements, and enable the training and learning to be constantly rehearsed and practised. The findings indicated that XR welding training devices could assist the learner to gain better hand stability skills as there was no real or actual heat or sparks generated in the XR welding simulators, which can be off-putting for the apprentice, which was identified earlier by Rusli, Zulkifli, Bin Saeed and Yussop (2019). This potential advancement in the learner's psychomotor skills was also noted by Chan, Haron, Isham, and Mohamed (2022), who found evidence that training in XR welding simulators improve hand stability and confidence amongst learners. This was also echoed by Jensen and Konradsen (2018), who outlined that using XR welding simulators for training led to the improvement of cognitive, psychomotor, and emotional abilities. There was also, as mentioned in the previous section, that unlike using the conventional PPE welding helmets, XR provided a high degree of visibility which enabled the learner to focus totally on the welding techniques needed (Kim & Lee, 2020). Reflecting this, this study found that XR training technology can be used to eliminate the fear of welding or to reduce the level of apprehension amongst new apprentices when gaining the fundamental skills. Since the environment is virtual, there is no consumption of physical welding coupons, welding electrodes, or the generation of the associated noise or usage of high levels of voltage and electricity, or the need to shield from gases such as CO2 or argon, which can be off-putting or restrictive for the learner to practice. While for the instructor, the usage of XR means that there is no need for the constant preparation and usage of materials, which can stop or pause the training session.

From the findings of the study, the usage of XR welding devices could be used to introduce and then enable the learner to practice and fine-tune their skills needed to become proficient in welding, therefore fast-tracking the overall learning process. This finding of enabling the learner to constantly practice and acquire the skills faster, supports the research of Cabero-Almenara, Fernández-Batanero, and Barroso (2019), who concluded that XR technologies could increase training performance and skills, but this study also extends the original work of Cabero-Almenara, Fernández-Batanero, and Barroso (2019), from a vocational training perspective, by identifying that training an apprentice needs to be a hybrid of XR and conventional training approaches. This perspective was also supported by Cai, Liu, Wang, Liu, and Liang (2021) and Cheng and Tsai (2012) who indicated that XR technologies potentially provided the participants with a virtual environment which could enable them to gain the necessary skills without the distractions associated with spot welding. In reaching this conclusion, this study contends that while XR welding training can assist learners to learn more effectively certain skills, there was a need for hands-on real also.

The study found another identified benefit of using XR welding simulators as a training tool for welding, was the removal of the need to constant re-calibrate the equipment and having to wear personal protective equipment. However, while these requirements were not needed when using XR technology, this study also contended that the learner still needs to have experienced and be familiar with these facets. This was supported by Troussas et al. (2022) who noted that re-calibration skills were essential for welding, and this could not be gained from the theory or via XR virtual reality.

To emerge from the study, which proved to be interesting, particularly as this project was conducted during COVID-19, was that the XR environment enabled the training to be conducted almost autonomously without the trainer's direct involvement or intervention. This automated non-trainer intervention meant that there was minimal contact between the learner and instructor, with the tutor simply required to monitor and advise the apprentice from a safe distance. The study found that the XR welding simulators could be run automatically after the initial setup, therefore enabling the learner more time to practice and reinforce their skills at their own pace, a theme originally identified by Agrawal and Pillai (2020), Da Dalta et al. (2010), who highlighted the necessity to re-practice their newly acquired skills.

When this study was first setup, there was a concern expressed by the instructors as to the logistics and movability of the simulators. Unlike the traditional welding training facilities, the study found that the XR technologies were seen as being relatively easy to set up and

move to the required and designated training area. This meant that it was possible for the welding training facility to quickly adapt to the pandemic safety requirements initiated by the UAE government and adhere to specified safety distances, but also enabled the equipment to be easily moved to be in the real welding environment if required, as means of introducing the workshop setting to the learner.

Overall, both the learners and instructors indicated that training with the simulators allowed the apprentices and tutors to track mistakes in real time and then correct them without the complication associated with a traditional welding setting. The instructor could view and assess how well the learner was performing the various welding tasks, and then after they have completed the welding process, then the entire activity could be jointly reviewed. The XR technologies also enabled both the learner and the tutor through a built-in display to highlight any errors the apprentice made in real time, allowing the opportunity to instantly correct any mistakes. The XR welding simulator also enabled each learner to create their own profile, which documented all their welding training activities and showed their performance and mistakes, so enabling the instructor and learner to accurately track progress. This finding supports the earlier work of Huang, Lou, Cheng and Chung (2020) and Da Dalto, Benus and Balet (2010), who stated that XR training simulator records personalised learning data, and learners can enter their accounts can create a personalised learning database then monitor and review progress.

Several of the apprentices and instructors in the study indicated that XR welding simulators were helpful, as the learners were able to overcome their fear of traditional welding, which occurred during the first cycle of this study. This study found that the learners thought that they could acquire the welding skills more efficiently through commencing with XR technology. For many of the learners, training by using the welding simulators was found to be simpler compared to traditional welding training techniques, and the experience was not hindered by the environment, the usage of wearing the PPE or waiting for their turn with the instructor. Reflecting this, the learners indicated that the training of welding should start with the XR simulators to gain the fundamental skills before being introduced to the actual equipment and environment, a finding which other studies including Jenson and Konradsen (2018), have omitted.

From the instructors' perspective, XR technologies could potentially speed up the training process, but the equipment also could enable them to assess each learner's progress and performance on a one-to-one basis or even as a cohort. These findings associated with the

instructor are consistent and support the previous study by Agrawal and Pillai (2020). In their study, Agrawal and Pillai (2020) observed that XR welding simulators apart from helping the learner to overcome their fear of arc welding, the technology also offered the means to measure performance and skills acquisition.

However, while the findings of the study identified substantial benefits associated with XR welding simulators, there are also limitations and challenges that need to be considered when training how to weld using XR technology. A significant challenge was that training using XR welding training technology was seen by both the learner and the instructor as being unable to replace hands-on training or as a replacement for the learner to use the conventional welding equipment. For the learners in this study, while simulator training had several benefits, the technology was seen only as a supplement to traditional training instead of being a viable replacement. One of the reasons for this perspective was that XR welding simulators could not reproduce the heat or recreate the potential hazards of the workplace. This potential inability to accurately replicate or reproduce the real world was supported by Hancock and Hoffman (2021), who concluded that XR technology is still unable to authentically replicate the physical experience, which was also supported by Pottle (2019), Smith (2019), Nebeling and Speicher (2018). However, unlike the above studies which were focused on investigating only XR technology, this study expands on this theme further by introducing both learning methodologies together.

The findings of this study identified that although the learners in this study were more relaxed with the use of XR welding training technology, even to the extent that the realism of simulators was seen as being practically real, and that there was no need for the use of PPE, which can be heavy and restrictive of the learners' movements, together with the visual impairment of the welding helmet, which is a common complaint associated with welding, however, the learners still acknowledged the importance of using and experiencing the conventional equipment. For these learners in this study, the perception was that without the actual experience, including wearing of the PPE, this could give the apprentice the wrong impression of the challenges and skills needed to weld accurately whilst wearing and using the required equipment. This was a unique finding of the study and has not been identified before, including by key writers in the field of XR technology, such as Jenson and Konradsen (2018), Smith (2019), Pottle (2019), Lavrentieva et al. (2020) or even in the area of welding including Johnson, Khan and Ophoff (2019).

The theme of safety was another key reason for seeing this technology as not a complete solution to training apprentices how to weld. Reflecting the work of Wanjari and Wankhede (2020) who highlighted the need for the learners to experience first-hand the potential hazards, this study concurred that the learning experience needs to enable the apprentice to manage the workplace setting in the future through fully understanding the dangers of this vocational environment. This also included the usage and wearing of equipment correctly. While the hazards of the welding environment can hinder the training process, it is imperative that the learners are exposed to this setting, so that they can be fully aware of the potential hazards and practice safety procedures. If the learner has insufficient exposure to the hazards of heat, sparks, fumes, and the electricity used when welding, then as identified in this study, the apprentice could be underprepared. Therefore, the exclusive use of XR welding simulators is not recommended. If the learners are not shown how to conduct the various welding tasks in a safe way, using the actual equipment they will be potentially at risk. This finding that XR technologies cannot effectively replace traditional welding equipment contradicts the earlier work of Izard et al. (2018). In their study, Izard et al. (2018), focused on virtual reality as a tool for education and training and then challenged the usage of conventional training as being the only means to educate learners. Izard et al. (2018) found that the traditional training experience was not as important as classroom instruction when using XR welding simulators, which this study challenges, and instead proposes a hybrid solution.

Part of the rationale for this proposed hybrid solution was seen in the interviews, as some of the learners highlighted that the XR equipment was unable to show welding damage, which can occur if the apprentice was moving too slowly or using very high welding settings, which can cause holes to appear in the metal. Also, the XR welding simulators were not able to replicate the process of needing to clean welds and remove any excess slag after a welding job is completed, which was seen as a gap in training knowledge, as observed by Hoffman (2008).

In summary, the findings of the study suggest that augmented and virtual reality has the potential to improve welding training, including in the areas of attaining fundamental psychomotor skills while also improving the confidence amongst the apprentices. Furthermore, the XR technology can provide a safe training environment for the learners to practice the fundamental techniques. In a vocational training setting, the XR technology did not need to be constantly re-calibrated and could track and correct the learner's mistakes and errors in real time. However, there are some limitations and associated challenges with the

usage of XR technology in a welding training setting. This includes the evidence from the findings that a XR methodology cannot fully replace using more conventional training methods to train technicians to weld. Therefore, this study contends that the use of virtual and augmented reality technologies needs to be in a hybrid format, which means the combination of conventional teaching techniques and XR, which challenges the original work of Izard et al. (2018). Through adopting this innovative hybrid strategy, XR technology can assist the learner to gain the confidence in acquiring the fundamental skills, but then progress and experience the reality of the real environment to consolidate their learning. The findings in this study, indicated that both the learners and the instructors saw the training process commencing with XR training then followed by traditional instruction in a real-life setting. These findings address the **first research question**: *what are the challenges and opportunities of implementing extended realities technologies in a vocational education setting in the UAE?* In achieving this research question as shown in Figure 6.1, the study has also addressed the first research gap as presented in Chapter Three, that while there has been increased academic interest into XR technology in academia (e.g., Smith, 2019; Pottle, 2019; Lavrentieva et al., 2020), this project has provided a new insight into determining the challenges of adopting AR/VR in teaching welding in the UAE by adopting an interventionist approach to generate real or active data, and found that the usage of XR as a training methodology can enhance the learning experience, but needs to be combined with more conventional training methods. The second research gap was also met as set out in Figure 3.1, as to conducting a study into XR, AR/VR training within the UAE vocational sector. Finally, in addressing the first research question, the sixth identified gap as presented in Figure 3.1, was met as to whether the UAE governmental led initiatives aimed at creating a strong knowledge-based economy which is driven by technological solutions could be achieved. This study found that extended reality technologies can be effectively used in vocational education in the UAE and can ultimately be part of the country's drive for a stronger knowledge-based economy from a vocational perspective but needs to be in a hybrid format (see Figure 6.1).

6.6 Apprentices learning experience when implementing AR/VR technology in vocational education in the UAE

Having outlined and discussed the opportunities and challenges associated with integrating XR, AR and VR technologies as a tool to train welding in the UAE, it is necessary to explore the learning experiences of the apprentices when using this technology. The findings from the learners focus groups found that using AR and VR welding simulators assisted them to

initially overcome their fear of welding. This perspective was due to the virtual environment having none of the distractions associated with the real environment, such as the heat and the sparks being generated, which the apprentices faced during the first cycle using the conventional welding equipment. There were also the added concerns or worries about consequences of making errors and the recognition that new training materials would need to be provided which were reported after the first cycle. As discussed in the previous section, the usage of XR technology also provided real-time feedback during the training activity, which enabled the learners to correct their mistakes if, and when they occurred. With this real-time feedback, the apprentices believed they became more proficient and could then rehearse or repeat the same procedure, whereby improving their welding skills without impacting on other learners. This ability to practice, gain feedback, and then re-practice also enabled the learner to gain the confidence in learning this specialised vocational skill. This finding was supported by Rusli, Zulkifli, Bin Saad, and Yussop (2019), who found that students using the mobile arc welding application tended to prefer to use new approaches to learn how to arc weld, particularly if the solution was incorporated into mobile technology such as augmented reality, as the experience was not impeded by the external welding environment. This theme of using XR technologies in welding training was extensively research by Lavrentieva et al. (2020) and earlier by Beaubien and Baker (2017), who indicated that XR in training is growing and is having a significant effect on vocational training welding which is assisting the learner to accelerate the transfer of knowledge and experience. For Lavrentieva et al. (2020) XR technology can be used to locate the learner in a virtual environment rather than a real and potentially harmful one, as the methodology can eliminate or remove the inherent hazards associated with welding, such as electrical sparks, gases, heat, and fire. Although unrelated to welding, Pottle (2019) and Smith (2019) both investigated the benefits of XR technology from a medical and aviation perspectives. The studies found that there was a possibility to recreate the physical experience but there were some limitations, which will be discussed later in this chapter.

To understand the benefits, this study observed that during the training session when the XR simulators were used, the learners were able to assess their performance through a digital indicator, which monitored their level of accuracy. This was seen as being more beneficial compared to the conventional way of learning how to weld, as the apprentice could easily see and understand where they needed to re-practice their skills, which concurs with the earlier work of Whitney and Stephens (2014), and more recently by Chan et al. (2022). The learners also reflected on how difficult it was to hear the instructor’s advice during the conventional

training session due to the external noises and the wearing of the required PPE. Interestingly, the XR performance indicators also introduced a competitive element to the learning experience, with the cohort attempting to outperform each other as to their level of welding accuracy, whereby promoting internal competition amongst the learners. This internal competitive aspect incentivized the learning environment, with learners trying to achieve the highest score possible in the cohort, therefore resulting in the apprentice to become more self-motivated.

Throughout the second and third cycle of the study, where the XR technology was incorporated into the learning experience, it was observed that those learners and instructors who had a strong background or familiarity with similar technology, such as using computers and tablets, were more willing to engage with the XR training methodology. Some of the learners in the focus groups also linked their experience of technology and compared it using the XR equipment to playing games on a PlayStation or on a personal computer. This perspective does challenge the earlier work of Bonner and Reinders (2018) and Johnston, Khan and Ophoff (2019), who independently concluded that XR technology can potentially be unsuitable or not viable to train an individual to perform a particular task due to the complexity of the technology. However, while being familiar with the equipment, there were however occasions when using the AR/VR technology, where the head-mounted display did not accurately provide the same experience as the traditional welding equipment. Part of this perception was related to the lack of authenticity of re-creating and simulating the welding experience, but also as to the weight of the AR/VR welding training helmets. This was because the headwear tended to have a camera, lights and a screen attached, therefore making the training headwear noticeably heavier, even compared to the heavy traditional welding helmet. This was compounded by the fact that the AR/VR welding simulator helmet also required data communication with the main XR welding unit and the power source, therefore the equipment was attached by a thick cable and close to a power source whereby restricting the learner's movement. This led to several learners complaining about minor discomfort when using the head-mounted display unit, a theme earlier explored but from a medical perspective by McKnight et al. (2019), who reported that learners were suffering from headaches, blurred vision and dizziness due to the headwear. While the helmet was heavier, the welding gun on the VR/AR was lighter than the one used in traditional welding. This was because the traditional welding machine gun cable consists of insulation materials designed around shielding the gas passage and the high voltage electrodes, whereas the AR/VR welding simulator only needed to have a cable for the data and power supply. This lightness of the welding gun also brought into question the authenticity of using this XR technology as

an accurate reflection of the real equipment used. This finding potentially challenges the study of Sheh et al. (2019), who advocated that XR technology has enabled the creation of different virtual environments which can engage the individual through their senses. However, this study found that XR technology has yet to replicate accurately the welding environment or the equipment. By reaching this conclusion, the study concurs with Feier and Banciu (2021) that the weight of the XR torches tend to be much lighter therefore the learner needs to handle and experience welding with the actual equipment. This study also addresses Wells and Miller's (2020) earlier question as to whether XR technology can effectively be used to train welding, as the XR equipment is not an exact replication. In response to Wells and Miller (2020), and the identified limitations as noted by Feier and Banciu (2021) this study acknowledges the limitations, but also highlights the benefits, but sees the usage of conventional and XR methodologies as being complimentary.

However, in a recent study by Santi et al. (2021) in investigating XR headwear and glasses, the authors noted that the visual side of XR technology still needs to be developed further to replicate the real world or experience, which was confirmed in this research project. Another example of the lack of reality in AR/VR welding training was that conventional welding equipment required the user to connect to a ground cable which was attached to the workbench or the piece to be welded. In contrast, XR welding methods do not require any grounding cables to be connected to the workpiece or to the welding table as there is no high voltage needed for the simulators. These differences as to reality and authenticity indicate that although XR simulators provide a similar experience to traditional welding equipment and despite the recognised benefits, this technology still lack some important aspects and therefore cannot completely replace the conventional welding training experience. From the findings, it is possible to conclude that the learners' saw that XR welding training technology can be an effective methodology, but there was still a need for the apprentices to learn to use and experience the conventional welding equipment also. Furthermore, the importance of the trainer as both a mentor and instructor remained relevant, as this was a theme earlier highlighted by Bryd et al. (2015) who questioned whether XR technology could effectively replace the instructor's role. In this study *there was no evidence to support this premise*. In reaching this conclusion, this study has addressed the **second research question**: *how does the students learning experience change when implementing extended realities technology in vocational education in the UAE?* As illustrated in Figure 6.1, in achieving the second research question, the third research gap was addressed, which was that current studies (e.g.,

Beaubien & Baker, 2017; Lavrentieva et al., 2020) still lacked a focus on learners' hands on experience acquired using XR technology compared to traditional methods. To address this gap, this study has conducted a project which has used both training methodologies, and then introduced a hybrid method, in cycle three, to conclude the research project. The fourth gap identified in Chapter Three also addressed that existing research (e.g., Jenson & Konradsen, 2018) indicated that technology can potentially provide a holistic learning experience, but what remained unclear was whether XR can effectively replace traditional training methodologies and approaches. This study identified the strengths and weaknesses of XR and conventional training methods, then drew on the benefits of each strategy to minimise or reduce the associated limitations of the other method. Finally, the study also addressed the fifth research gap, that past research (e.g., Jenson & Konradsen, 2018) has only focused on the benefits of introducing AR/VR in training rather than whether extended reality technology can be effectively deployed in welding training to train future apprentices (see Figure 3.1). This study with a focus on training apprentices to weld in the UAE, has found that XR technology can be deployed effectively, but there is a need to recognise there are some limitations, such as the lack of authenticity to replicate the real-welding environment, the inability to reproduce the hazardous workshop setting and the need for the learner to be able to use the actual equipment.

6.7 Instructor training experience when implementing augmented reality and virtual reality technology in vocational education in the UAE

The study also documented the experiences of the instructors as they used the XR technology to train the apprentices to weld. The findings of the study from the instructor's perspective indicated that there were minimal complications or disruptions when using the XR welding simulator compared to using the conventional methodology to train the apprentices. The study found that firstly the use of the XR technology enabled a seamless training experience to occur, and permitted the instructor to manage the learners more effectively in the learning environment. This finding concurs with Seagull, Moses, and Park (2008) who found that the benefits of VR simplified the training tasks, except their study was based on medical surgery activities. In an unrelated medical study into the usage of XR technology to train surgeons, Maresky et al. (2019) found that certain procedures benefited from the use of this form of technology. From a welding perspective, this study also found that there were several identified benefits for the instructor which included that XR technology enabled the tutor in real time to monitor the individual's and cohort's progress. With XR, the instructor was able

to divide the class into multiple groups and then provide these groups with different types of training tasks, while also enabling the instructor to monitor the learner's progress. This was in contrast to the conventional means to training welding techniques, where the instructor could only provide one-to-one training on an individualised basis. With the use of XR technology, the recognised safety issues associated with welding was not seen as being a potential barrier to the acquisition of important skills and techniques, as the apprentice was able to work independently without the active involvement of the instructor, as the associated hazards were not present.

The instructors also noted that the use of AR and VR technology enabled and promoted better communication of errors when training compared to using traditional welding equipment, as training an apprentice to weld in a real-world setting usually produced a high level of noise which can limit communication between the instructor and the learner. The findings further revealed that the instructor could indicate where mistakes had occurred and then guide the learner as to how to rectify them in real time, as both the apprentice and instructor could see the welding simulator screen. Finally, the instructors also indicated that it was possible to evaluate the performance of the learner retrospectively, and the accuracy of the reporting tool could be used as a reliable methodology to identify to the learner areas for future practice. This finding was also linked to the perspective of time dedicated to the task of training an apprentice to weld, as the instructors identified that the XR technology meant that the physical training materials were not needed to be prepared, a theme identified by Hancock (2009) as a potential constraint when training apprentices to weld, and then by eliminating this requirement, could enable the instructor to spend more time monitoring and guiding the learner.

However, this study also found that there was still a recognised need amongst the learners and the instructors that in the context of welding education, unlike Seagull, Moses, and Park (2008) that the actual experience of the vocational task and equipment was still needed. Both the instructors and the apprentices on reflection acknowledged the importance of handling and using the real equipment, to wear the restrictive PPE, and experience working in the physical welding environment. From the instructors' perspective, the XR welding simulators while providing some significant benefits, the technology was still seen as not being a complete replacement for the apprentice to learn how to weld. Part of this could be attributed to the lack of authenticity of the technology as previously discussed, in that it was unable to replicate the possible dangers and risks associated with welding. This lack of authenticity was seen by the fact that the virtual environment removed the actual hazards and risks, which

could lead to the learner becoming overconfident and complacent to potential risks. For the instructors, the learners still needed to be exposed to the real welding environment and needing to operate in a potentially hazardous workshop setting as part of safety training. Reflecting this perspective of the instructors, while XR welding simulators can potentially assist in the teaching of fundamental theory, practice, and knowledge, this technology should be used in conjunction with practical hands-on welding instruction. In reaching this conclusion, the instructors also highlighted that when starting to train apprentices to weld, there should be a blend of integrated virtual reality with real-world instruction. For example, rather than the apprentice being faced with the hazards of welding and the need to wear restrictive PPE, practising with AR/VR can enable the learner to pick up the basic techniques before progressing to experience welding in a real setting. For the instructors in this study, the usage of a hybrid XR technology and conventional welding solution provided the best means of training apprentices in the foundations and fundamentals of welding. The findings of this study revealed that using a blended approach, combining XR welding simulators with traditional welding training, can provide the apprentices with a holistic and rich welding training experience, which balances techniques with safety, whereby enabling the learner to constantly practice their newly acquired skills, before progressing on to using the actual equipment.

While the findings of this study indicated that the instructors had an openness to using a blended approach to train apprentices to weld, Jensen and Konradsen (2018) earlier indicated that many educational applications of AR/VR technologies are solely oriented for self-study and not used in a vocational classroom setting. Therefore, this study has extended the original research of Jensen and Konradsen (2018), by providing evidence of the use of a XR methodology into a vocational setting and has highlighted the effectiveness of using this technology in conjunction with more traditional training methods. Therefore, the outcome of this finding, was that training apprentices in the future to weld in the UAE would benefit from using a combination or hybrid solution of AR and VR welding simulators together with the conventional welding equipment. However, to be effective, the sequence of the learning process needs to commence with the use of XR technology where the fundamental skills and techniques are acquired, before the learner is introduced to the real or actual environment. The conclusion as shown in Figure 6.1, is that a hybrid approach could potentially be an effective means of training apprentices to weld, whereby addressing the third research question: *what is the instructor / trainers experience of implementing extended realities technology in vocational education in UAE?* By addressing the third research question, this

study has also addressed the third research gap set out in Figure 3.1, by comparing the use of conventional welding training methods with the XR reality equipment. The study found that there are benefits and associated limitations of both approaches, but with a hybrid and strategic usage of the two, the methodologies could be combined to provide a more holistic vocational experience. The study in meeting the third research question also addressed the fourth gap of knowledge as set out in Figure 3.1, in that XR technology is still unable to replicate the actual welding experience, but can be used effectively to enable the learners to gain the fundamental skills and techniques before being introduced to the actual equipment and the environment. Finally, the fifth gap was also addressed, by conducting a research study to provide a much richer insight into training apprentices to weld from both the conventional and XR technology perspectives, as opposed to focusing and studying one method only.

6.8 Chapter Summary

This Chapter has critically discussed the outcome of the study as presented in Chapter Five as to how future technicians can be trained to gain the necessary welding skills, by conducting a research project which included using three independent intervention cycles, compared to the current academic debate as presented in Chapter Two and Three. This discussion chapter was based on addressing the central aim of the study, which was *to investigate the potential benefits and challenges associated with implementing extended reality technologies in a technical and vocational educational setting in the UAE to train apprentices to weld*. In addressing this aim, this Chapter contends that to meet the UAE governmental-led initiative to create a strong knowledge-based economy through embracing technological solutions to achieve the nation's Vision 2030, however this study contends that conventional welding training methods needs still to be a part of the training process.

To represent visually this Chapter and the critical discussion, Figure 6.1 provides a summary of the key findings. Following an intervention research approach, the interviews from the focus groups and one-to-one semi-structured interviews captured the experiences and perceptions of both the instructors and apprentices when training using traditional welding equipment, then through the usage of XR welding simulators. This Chapter has highlighted and critically discussed the benefits of training the apprentices to weld using traditional welding equipment, which included how to handle and use the actual welding resources, while also being exposed to the potential hazards in a real workshop environment. This approach enabled the learner to have an extensive first-hand experience and knowledge of safety requirements, while understanding potential hazards. The conventional training

environment also enabled the learner to be able to re-calibrate the equipment whilst working in a restricted and often dangerous setting, which were key skills needed when learning how to weld (Okimoto, Okimoto & Goldbach, 2015; Stone, McLaurin Zhong & Watts, 2013; Papakostas, Troussas, Krouska & Sgouropoulou, 2022). This theme and findings are represented in Figure 6.1, Findings #2.

However, the conventional training methodology does have its challenges associated with training apprentices to weld. In this study, as shown in Figure 6.1, Findings #2, the first cycle of the project identified that the welding workshop environment was often seen as not conducive to training a cohort of learners. This was due to the instructor needing to train the techniques on an individual basis. There was also the need for the instructor needing to stop the session as they prepared new materials for the learner. As a result, the learner often became disengaged and their perception and attitude as to learning how to weld reduced. The study also found that the environment could hamper or impede the learning experience, as both the instructor and apprentice found it hard to communicate to each other due to the headwear being worn and the noise of the workshop. Finally, the apprentices highlighted that the PPE was restrictive and that most of the learners were initially fearful of the noise of the electricity and sparks being generated.

The study then moved onto implement an AR and VR technological solution into the welding training environment. A major theme identified in this study was that using AR and VR technology in welding training can enhance the traditional training experience, which was a key finding as shown in Figure 6.1, Findings #3. For example, XR welding simulators can also assist the instructor to deliver the training of welding to a group of learners without the need for one-to-one tuition, which often impeded the learning experience.

There were also various psychological and behavioural benefits, in using XR technology to train apprentices to weld, including giving the individual the confidence to gain the fundamental skills before experiencing the real environment. The usage also promoted the learner to engage more as they had dedicated equipment, real-time information and the means to monitor performance and ability. This enabled the individual learner to gain the basic psychomotor attributes such as hand stability, and eye and hand coordination skills, which are essential aspects when mastering how to weld. But also, with XR technology, the equipment provided real-time information, therefore the learner had the ability to compare their skills levels with other members of the cohort, whereby increasing self-motivation. Finally, the

findings found that the learner because of their dedicated training simulator, the individual was able to re-practice and correct their welding techniques, as indicated in Finding #1, as presented in Figure 6.1 which agrees with, but then extends the original work of Pottie (2019), Smith (2019) and Lavrentieva et al. (2020), who unlike this study focused on the XR reality usage only to contend that XR technology had significant benefits, while this study recognises the benefits, but also identified limitations, but argued that these can be addressed by using more traditional and conventional methods.

The use of XR technology as a potential training welding tool does have its limitations as being seen as not being sufficiently robust to be used as a standalone methodology. This study found that there was a lack of authenticity when using XR technology, as it was unable to replicate the possible dangers and risks associated with welding, which could lead to the learner not appreciating the potential hazards of this vocational activity. There was also the fact that the XR equipment could not accurately replicate how the welding gun performed. At the same time, the study found the learner also highlighted that the visual display was unable to represent the welding activity accurately and that often the XR headwear used was heavy and awkward to use.

Reflecting these limitations, during the third and final cycle of this study, there was a recognition amongst the learners and the instructors that a hybrid or combination of traditional welding equipment and XR technologies was the most effective approach. This hybrid approach provides a unique learning strategy as to training vocational apprentices how to weld. This outcome and discussion are depicted in Figure 6.1, which are shown in Finding in number 4 and number 5, as to how a hybrid approach can provide a holistic learning experience, which builds on and challenges the original perspective of Jenson and Konradsen (2018), that XR technology can be beneficial, but this study also acknowledges the need for conventional training methodologies still.

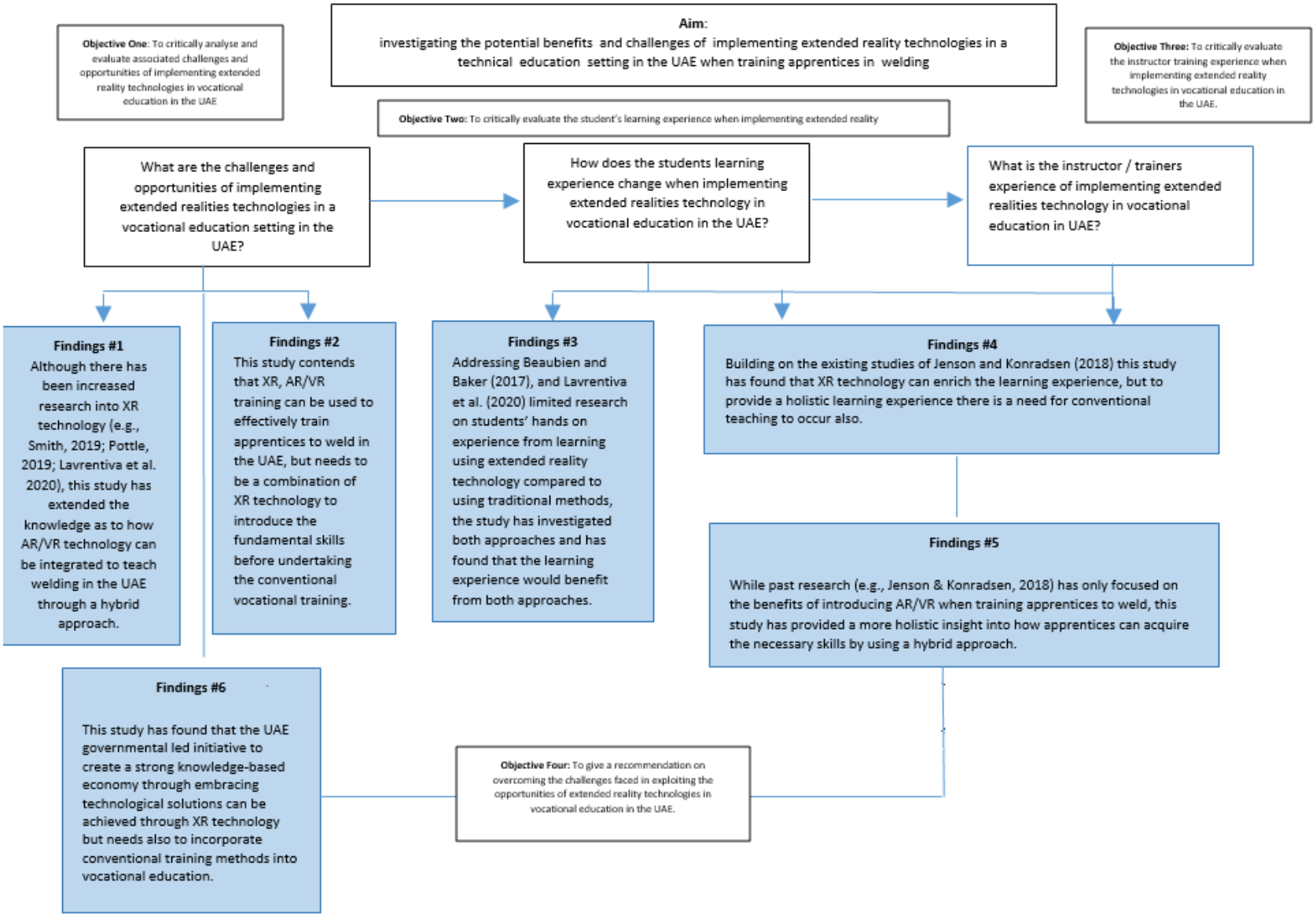

Figure 6.1 The Discussion Conceptual Model

Chapter Seven
Conceptual Discussion

7.1 Introduction

This Chapter will set out the conceptual findings and critical discussion of this study, addressing the aim of the project: *to investigate the potential benefits and challenges of implementing extended reality technologies in a technical education setting in the UAE when training apprentices in welding.* In achieving the aim of the research, the following research objectives were met, which will commence with research question one. **Research objective one** was focused on *critically analysing and evaluating the associated challenges and opportunities of implementing XR technology in the UAE vocational education setting to training welding.* Through conducting both the contextual and conceptual literature reviews, there were six gaps identified as presented in Chapter Three, Figure 3.1. The first gap was that although there is existing literature related to the challenges (e.g., Bonner & Reinder, 2018; Johnston, Khan & Ophoff, 2019) and benefits (e.g., Jensen & Konradsen, 2018; Chan, Haron, Isham & Mohamed, 2022; Kim & Lee, 2020) associated with using extended reality for training, there is an existing lack of academic understanding as to the challenges of adopting this technological solution in the UAE. Drawing on the existing literature, for example, Smith (2019) and Pottle (2019), these studies have shown that XR technology can provide vocational training solutions, but from a medical perspective. More recently, there have been studies conducted as to using XR technology to train welding (e.g., Agrawal & Pillai, 2020; Da Dalta et al., 2010), but the focus has been on benefits as opposed to a holistic account of the sessions using both traditional and XR technology in a single project, and limited research from a UAE vocational perspective. The second gap identified from the literature review, which was related to the first research objective, was that while there is increased academic interest in the area of extended reality, which has included studies by Johnson, Khan and Ophoff (2019), there has been notably little published from a vocational UAE perspective, which this study has addressed. This gap was also aligned closely with the **fourth research objective**: *as to whether the UAE government-led initiative can become a smart technological-based economy by exploiting the opportunities of extended reality technologies in vocational education in the UAE.*

The conceptual literature review Chapter Three revealed another gap in existing knowledge which is aligned with the **second research objective**: *to critically evaluate the instructor training experience when implementing XR technologies in vocational education in the UAE*, as to whether the actual experiences of the learner can acquire the necessary vocational skills from using extended reality technology or whether a traditional modes of learning mode is more suitable. Partly addressing this, studies by Beaubien and Baker (2017) and Lavrentiva et al. (2020), while informative, have not accurately captured the learner's or the instructor's experiences as the training process progressed, and have only captured the perspectives of XR technology.

In addressing the **second research objective**: *to critically evaluate the student's learning experience when implementing extended reality technologies in vocational education in the UAE,* there has emerged from the existing literature two gaps, which have been aligned together with the **third research objective**: *to critically evaluate the instructor training experience when implementing extended reality technologies in vocational education in the UAE*, emerged. The first gap is shown in Figure 7.1 which was presented originally in Chapter Three, was to whether extended reality can provide a holistic learning experience and whether this technology can replace traditional welding methodologies as advocated by Jenson and Konradsen (2018). The second gap as shown in Figure 7.1, which emerged from research objectives two and three was that although the benefits have been arguably extensively explored (e.g., Cabero-Almenara, Fernández-Batanero & Barroso, 2019), what remains unclear is whether the potential challenges and benefits experienced by a learner are the same as the instructors, if a joint or combined training approach is adopted.

Finally, in addressing the final **research objective four**, *to provide a recommendation on overcoming the challenges faced in exploiting the opportunities of extended reality technologies in vocational education in the UAE*, as shown in Figure 7.1, the literature review revealed, as presented in Chapter Three, that there was limited research conducted as to whether extended reality can enable the UAE to become a strong knowledge-based economy, or does this technology also need the traditional modes of learning to enhance the apprentice's experience when learning how to weld. Reflecting above this, Chapter will critically present the conceptual implications of whether welding can be effectively implemented in a technical vocational education setting in the UAE, to train apprentices to weld.

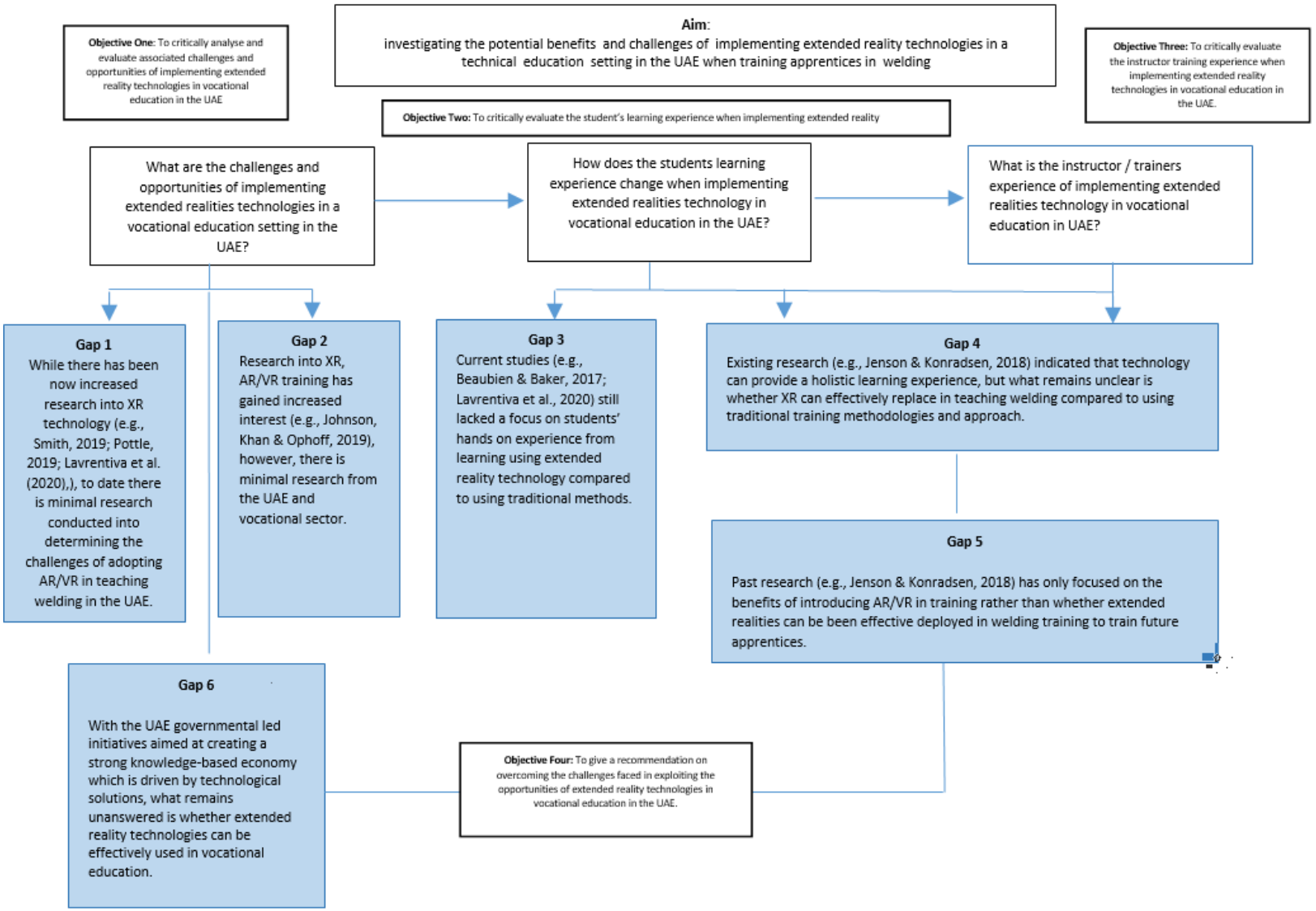

Figure 7.1 Literature review conceptual framework

7.2 Conceptual knowledge

The empirical findings of this study have shown that training with XR technology can potentially enable apprentices to weld, and improve the overall experience of both the learner and the instructors. For the instructor, XR technology can overcome and mitigate some of the challenges associated with traditional welding training methods, such as the need for one-to-one instruction, while the rest of the cohort needs to wait, the need for resources to be pre-prepared and then replenished during the session, and the poor communication between the learner and the instructor. For the apprentice, the utilisation of the XR tools can helped to introduce the individual to the fundamentals and skills needed for welding, including hand-eye coordination attributes. There was also the elimination of the distractions associated with the actual welding environment, which included the associated sparks being generated together with the heat, smells, and noise of the workshop setting, which were initially seen as impeding the learning experience. This was also compounded by the need for the apprentice to wear the protective equipment, such as the welding helmet, which had poor visibility. The study found particularly during the first cycle, that the trainees highlighted the lack of confidence when operating the real welding equipment, and identified the need to gain then improve their psychomotor skills which required constant practice, while also experiencing a sense of fear and anxiety.

To determine, unlike other previous studies, including Stone et al. (2013) and Papakostas et al. (2022), this study then focused on introducing XR technology to train apprentices to weld. In introducing this methodology into a vocational training session, the findings found that for the instructor, the benefit of removing the need for one-to-one instruction, the constant replenishing of the resources and the ease of communication, which was a challenge for conducting a welding training session using the real or authentic equipment. For the apprentices, they identified that XR technology enabled them to practice and re-practice their newly acquired skills in a setting which was free of the challenges of the workshop environment, such as the heat, noise and smells together with the lack of sparks and the fear of the electricity being removed. However, while there were clear benefits of using XR technology, the study contended that XR had distinct limitations, such as the lack of authenticity compared to using the real welding equipment, and on reflection for the apprentices the need for hands-on experience of the sparks, noise, heat and smells being generated, as safety awareness was essential. Therefore, it can be concluded that XR technology cannot fully replace traditional welding training methods currently. This partly

contradicts the findings of Izard et al. (2018), who argued that extended reality technologies were a tool for education and training that could replace conventional training practices.

Reflecting the above, this study and based on the feedback during the first two cycles, contended that there was a need for a hybrid approach to training welding. This approach would enable the weaknesses of one method to be addressed by the strengths of the other methodology and vice versa. However, as noted in the findings chapter, Chapter Five, the sequence of the methodologies was important. This study found that the third cycle revealed that XR welding simulators needed to commence first, before the apprentice is exposed to the actual workshop environment. This was informed and suggested by the apprentices during the second cycle. Commencing with the XR technology the learners could gain the basic skills, including the eye-hand coordination attributes and the confidence needed to progress to use the actual physical environment, but the reality of welding still needed to be replicated in a workshop setting using the real welding tools. This study found that extended reality technology could not completely replace traditional welding equipment in a training session.

7.3 Addressing the identified research gaps

In Figure 7.2 below, the original conceptual framework has been updated with the findings of the study to create a practical conceptual framework, informed by Chapter Six, Figure 6.1, which was related to the critical discussion. In addressing the ***first gap***, this study contends that the XR technology unlike the earlier work of Smith (2019) and Pottle (2019) is unable to recreate accurately the traditional welding workshop, even though the setting can be off-putting for the apprentices initially, both the instructors and learners still needed to experience the actual equipment and understand the associated safety risks.

In addressing the second gap, which focused on the theme of vocational education and whether welding could be delivered solely through XR technology. The study found that XR could enable the learners to gain a proficient level of eye and hand coordination and the fundamental of welding, like angles, without the challenges associated risk and safety issues. With the technology, the apprentices and instructors using XR technology were able to gain real-time feedback, while training using the conventional equipment was often retrospective and impeded by poor communications due to the noise and restrictions of the PPE, a theme identified earlier by Lombardi et al. (2005, 2009).

To address the ***third research gap***, the study built on the earlier work of Beaubein and Baker (2017), and Lavrentiva et al. (2020) found that the third cycle of the research project in providing a hybrid training approach can assist in overcoming the challenges and fears associated with using the physical aspects of welding when initially learning the fundamental skills. In focusing on ***research gaps 4 and 5***, writers such as Jenson and Konradsen (2018) and Chakradhar et al. (2022) contended that a XR solution can provide an acceptable vocational experience, however this study challenges this perspective, and contends that there still a need for authenticity. Authenticity such as the handling of the equipment and using the actual resources, as there are differences in the weight of the real welding torches, exposure to the external environment, like the sparks, heat, noise, and smells generated which was an essential learning experience, which feeds into the need for the apprentices to be aware of safety issues and how to re-calibrate the equipment. Linked to this was the importance associated with the availability of the instructor and the time to practice. While XR technology provided this, the associated limitations of the actual welding environment were still needed. Finally, in addressing the ***sixth research gap***, as to whether introducing XR technology can assist the UAE Vision 2030, this study contended that the methodology can assist in the country becoming a knowledge-based economy, but needs also the more traditional mode of training apprentices in a various technical training courses due to the potential limitations of extended reality.

Extended reality does however have the potential to revolutionise vocational training across various industries, including welding, contributing to the strategic vision of the UAE becoming a knowledge-based economy. By enhancing the learning experiences of trainees and instructors, improving the overall quality of vocational training, and empowering individuals to acquire the skills needed for a knowledge-based economy, extended reality can play a crucial role in shaping the future of vocational education.

There is also the cost-effective aspect of the solution, which combines XR training methods with traditional equipment, whereby enabling vocational training institutions to offer a wider range of courses and reach a larger number of individuals, therefore fostering a highly skilled workforce aligned with the knowledge-based economy vision.

By harnessing the potential of virtual reality technologies in vocational training across different sectors, the UAE can cultivate a highly skilled workforce, supporting the strategic vision of becoming a knowledge-based economy. The integration of extended reality with traditional methods into vocational training has the potential to enhance learning experiences and offer cost-effective training solutions.

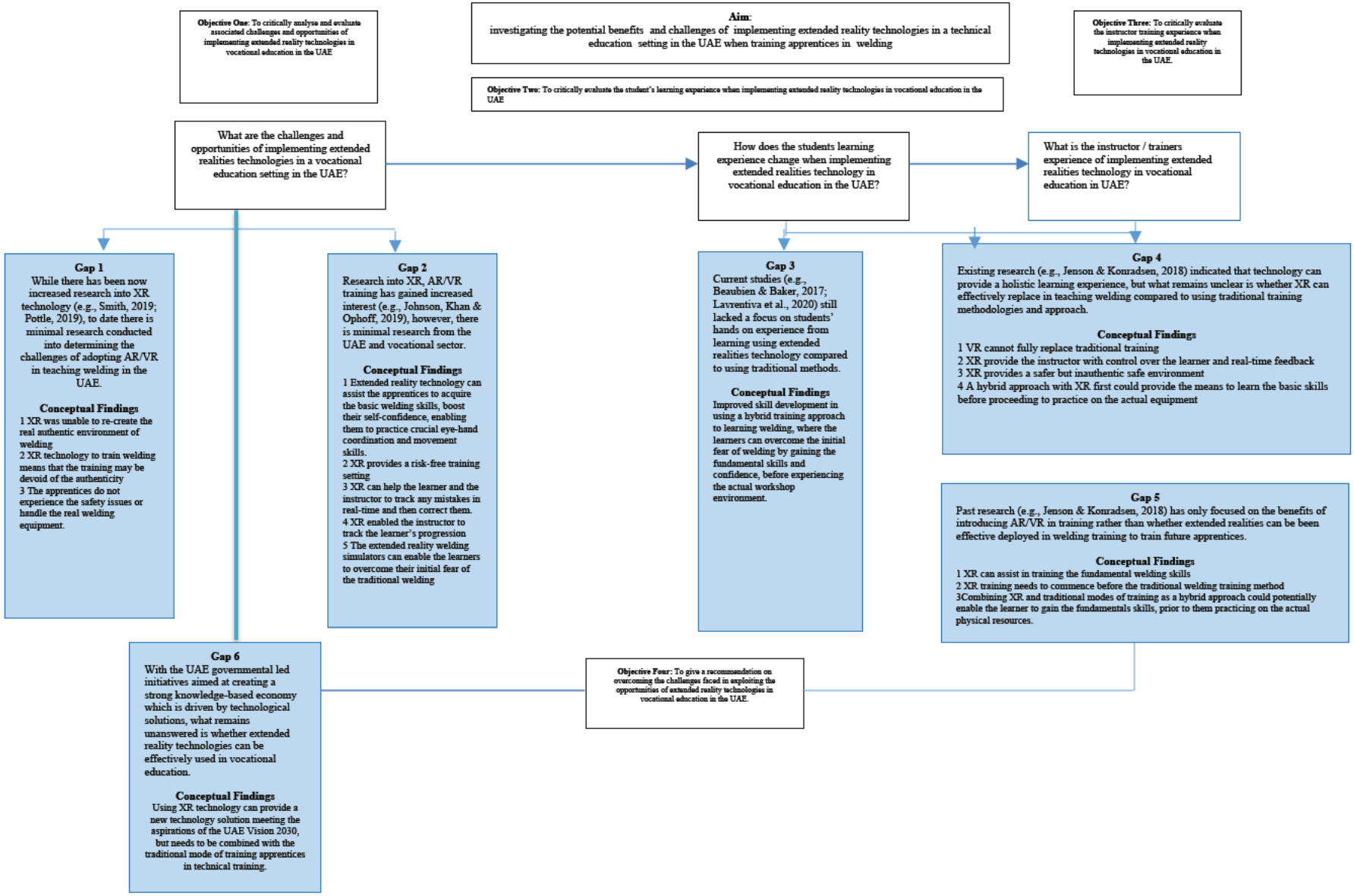

Figure 7.2 Practical Conceptual Framework

7.4 Practical conceptual framework connected to the research themes

Figure 7.3 which is presented below provides an updated conceptual framework which has been informed by the findings together with the related themes and codes. The ***first research gap*** as presented in Figure 7.3, is that the XR technology is unable to recreate accurately the traditional welding workshop environment for either the students or instructors. For the learners, the handling of the actual equipment and understanding the associated risks in a welding workshop environment was paramount. The themes and codes connected to the first gap were: Theme 6 (code 6.2), and Theme 9 (code 1).

In relation to the ***second research gap***, the study found that XR could empower students to gain a higher level of dexterity as to hand-eye coordination along with gaining basic welding techniques, like welding angles, without the distractions or challenges associated with the actual welding environment. The themes that were connected to the second gap were: Theme 4 (codes 1, 2 and 4), Theme 10 (codes 4 and 8), Theme 5 (codes 1 and 3), Theme 6 (code 2) and finally, Theme 8 (code 1).

In the ***third research gap***, the study found that a hybrid training method can assist in overcoming the initially challenges and fears associated with training using traditional welding equipment in a real workshop. The themes that were related to the findings of the third gap were: Theme 7 (codes 1 and 2) and Theme 9(code 1).

In addressing the ***fourth research gap,*** the study proposes that while XR technology can offer a satisfactory vocational experience, authenticity is still required. This authenticity includes the actual handling of the welding equipment, exposure to the hazards and risks of the workshop environment, the availability of instructors and having sufficient time to practice. Authenticity was also essential to the apprentices to be aware of safety issues and how to re-calibrate the welding equipment when needed. The themes that were connected to the findings of the fourth gap were: Theme 6 (code 2), Theme 10 (codes 1 and 8), Theme 3 (code 3) and Theme 7 (code 2).

Finally, in focusing on the ***fifth research gap***, the study found that an XR solution can provide an acceptable vocational experience, however, there was still a need to determine whether this technology of extended reality can be effectively deployed in welding vocational training. The themes that were related to the findings of the third gap were: Theme 4 (codes 1, 2 and 4) and Theme 5 (codes 2 and 4).

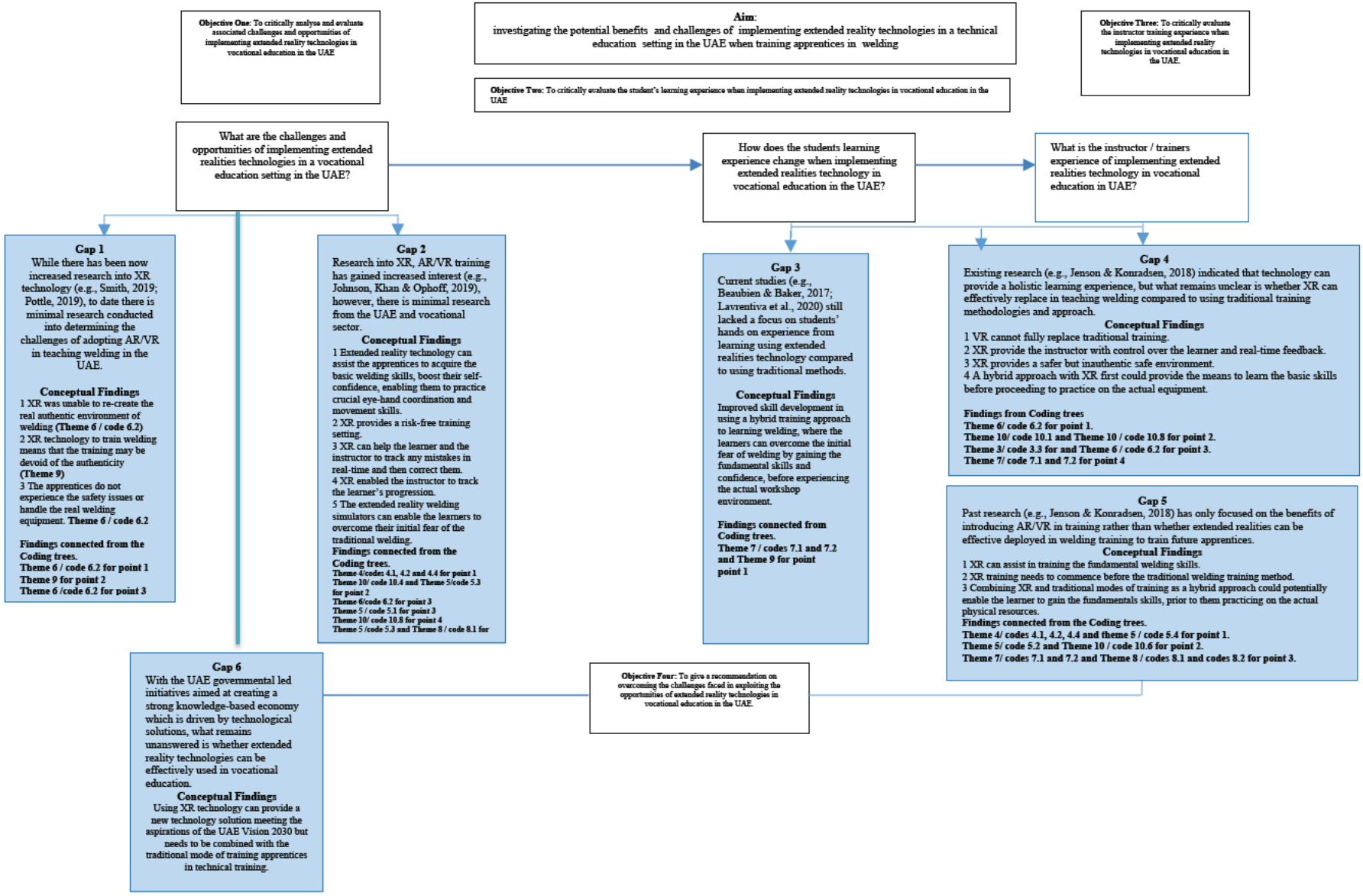

Figure 7.3 Practical Conceptual Framework Connected with themes

7.5 Comparison of the three Training methods - Traditional Training (TT), Extended Reality (XR) and Combination methods of TT and XR)

Concepts	Training with Traditional Training method	Training with extended reality method	Training with Combination methods (TT & XR)
XR can help the learner and the instructor to track any mistakes in real-time and then correct them.	NOT available due to the sparks and noise generated from the welding process.	Available from the beginning and benefited the student to correct mistakes	Available from the beginning and it benefit the learner to correct mistakes
The apprentices do not experience the safety issues or handle the real welding equipment.	Poor ventilation environment with hazards that can lead to injuries	Ideal safe training environment	Controlling hazards due to the starting training with XR then safety orientation, followed by traditional training
Extended reality technology can assist the apprentices to acquire the basic welding skills, boost their self-confidence, enabling them to practice crucial eye-hand coordination and movement skills.	Slow progress in gaining the required psychomotor skills	Fast progression in psychomotor skills	Fast progression in psychomotor skills
XR technology to train welding means that the training may be devoid of the authenticity	Authentic experience	Non-authentic experience	Training with the two methods can provide greater the authenticity
The extended reality welding simulators can enable the learners to overcome their initial fear of the traditional welding	Potential fears with the learners due to the spark and noise	Little fears as students gain confidence	Little fears as learners gained confidence
Extended reality provides the instructor with control over the learner and real-time feedback.	Less control	Better control of the students due to the engagement of students	Better controlling the learners due to the engagement of students
Extended reality was unable to re-create the real authentic environment of welding	Replicates the real environment	Cannot replicate the real world of a welding environment such as the sparks and heat	Replicate real environment due to the combination of the two training methods
XR was unable to re-create the real authentic environment of welding	Difficult due to the challenges of poor environment and hazards	The training was beneficial however does not replicate the reality of the welding workshop	Seamless training replicating the reality of the welding workshop.

Table 7-1 Comparison between training methods

7.6 Chapter Summary

This Chapter has set out the critical discussion and then conceptualized the findings of this study, as to how the study has addressed the aim of the project: *to investigate the potential benefits and challenges of implementing extended reality technologies in a technical education setting in the UAE when training apprentices in welding.* In presenting this, the Chapter has updated the conceptual framework as originally presented in Chapter Three, Figure 3.1, which was then informed by Chapter Six, Figure 6.1. Overall, the practical conceptual construction using XR and the conventional welding methods, indicates that the limitations and challenges of one methodology can be offset by the benefits of the other. Through using an interventionist approach and adopting an action research strategy of three independent cycles, this study has uniquely found that a hybrid solution is most suitable to train vocational apprentices to weld.

Chapter Eight
Conclusion

8.1 Introduction

Following the presentation of the results and the discussion of the findings in this study, as set out in Chapter Five and Chapter Six, this chapter will present a critical review and summary of the experiences of the learners and instructors as to using traditional and extended reality techniques when learning how to weld in the UAE's technical and vocational education and training. This Chapter will include setting out the intention of the study, and how the aim and objectives were achieved, the contribution to business practice and academic understanding, before providing an insight into the limitations of the study and areas for future research. In achieving this, the Chapter will also consider how the findings contribute to the body of knowledge and practice within the TVET and how welding training can benefit from using a hybrid approach of using traditional training practices combined with extended reality (XR) technologies, as this study is a professional doctorate.

8.2 Aim of the Research

The study was based on investigating the potential benefits and challenges of implementing extended reality technologies in a technical educational setting in the UAE when training apprentices in welding. To achieve this, the study addressed the following research objectives:

Objective One: To critically analyse and evaluate associated challenges and opportunities of implementing extended reality technologies in vocational education in the UAE.

Objective Two: To critically evaluate the student's learning experience when implementing extended reality technologies in vocational education in the UAE.

Objective Three: To critically evaluate the instructor training experience when implementing extended reality technologies in vocational education in the UAE.

Objective Four: To give a recommendation on overcoming the challenges faced in exploiting the opportunities of extended reality technologies in vocational education in the UAE.

In achieving these research objectives and ultimately the aim, the intention of the study was to provide a new critical insight into whether an innovative training environment using extended reality technology could be implemented effectively in a welding setting. In achieving this, the study focused on determining whether XR technology can enhance, replace or potentially be detrimental to learning how to weld. The study also wanted to know whether the learners would possess the necessary psychomotor skills needed to meet the challenges associated with welding. To achieve this, the study adopted an interventionist approach to generate real data as opposed to simply proving or falsifying a pre-determined hypothesis or generate a new untested theory. The rationale for this decision is presented in the next section.

8.3 Overview of the Study

To generate and bring about real change within a doctorate study which was in TVET in the UAE, the study adopted an interventionist research approach which comprised of three independent action cycles where both apprentices and instructors were interviewed and observed throughout the cycles. As set out in Chapter Four and Five, cycle one comprised of apprentice learning how to weld in a traditional welding setting which included using conventional resources, equipment, and materials, wearing the protective clothing while practicing and learning in the restrictive environment of heat, sparks and smells. In contrast, cycle two comprised of apprentices experiencing being trained using extended reality technology which enabled them to gain and then practice basic welding techniques. Then based on the findings of the participants experiences and observations from cycle one and two, cycle three was created. Cycle three became a hybrid approach of traditional and extended reality welding training, where the learners used extended reality initially to learn the fundamentals to welding before being exposed to the authentic real welding environment.

Throughout each of these cycles, the learners and instructors were interviewed using a focus group and one to one interview approach, and their behaviour was observed by the researcher during the training sessions. Reflecting on Krueger and Casey (2014) declares that the purpose of using a focus group was to encourage group cohesion among individuals who have similar interests and values, this study intentionally encouraged open dialogue and promoted critical reflection amongst the learners as to their learning experiences. Morgan (1996) and Kvale (2008) both argued that focus groups are most effective when combined with other approaches, including interviews and observations, whereby enabling a more robust perspective to be generated. As this study adopted a qualitative methodology to gather the data which was captured using a constructivist perspective with the study using semi-structured interviews with

the instructors and focus groups for the apprentices and then the findings were analysed. Through following this strategy, the approach can enable the researcher to engage with the participant's perspectives and experiences through providing context and meaning to provide an extensive account of the participants viewpoints as the research developed (Creswell, 2018). Using this inductive strategy, the focus group and interviews were recorded, transcribed, and analysed in Arabic using a thematic analysis approach as prescribed by Braun and Clarke (2013). The findings were evaluated against existing knowledge and then as the research progressed, a comparison was conducted as to each cycle, which then informed the next phase of the research project, which enabled real data outcomes to be generated. By using this strategy, the intention was to evaluate the findings to develop a set of recommendations for the TVET when training welding in the future in the UAE in a vocational training setting.

8.4 Summary of the key findings

This section will outline how the research objectives were achieved and how the overall aim of the research: to investigate the potential benefits and challenges of implementing extended reality technologies in technical education in the UAE when training apprentices in welding, was attained.

In achieving the **first research objective** to critical evaluate and analyse the challenges and opportunities associated with implementing extended reality technologies in welding training as series of key findings were identified and presented in the previous chapter, Chapter Six. In addressing this research question, the challenges associated with extended reality will be presented first in this section. As set out in Chapter Five and Chapter Six, the findings identified several challenges of adopting extended reality technologies in a vocational welding setting. One major challenge was that extended reality while potentially being an effective tool to learn the fundamentals of welding, the technology was unable to re-create the real authentic environment of welding, where heat, smell, and sparks dominate the working environment. There was also the evidence from the focus groups that while the learners gained the basic skills, the reality of welding meant that the training was devoid of the authenticity of the overall experience, for example, handling and managing of the heavy welding equipment and the use of the restrictive protective clothing, which neither could be simulated using extended reality welding simulator. The participants in this research acknowledged that there were many advantages of using extended reality in welding training, but they also highlighted that these extended reality technologies could not fully replace traditional welding equipment in vocational training. As mentioned above, one of the reasons

for this perspective was that extended reality welding simulators could not authentically reproduce the heat or recreate the potential hazards of the workplace. These hazards are main the part of the safety awareness training and were seen by both the apprentices and instructors as an essential part of the overall learning experience, despite the initial wariness of the learners. For many of the learners and the tutors, there was an acknowledgement that the apprentice needed to be adequately prepared for welding in an industrial context, therefore safety awareness and being exposed to the heat, sparks, gases, radiations, and electricity was an essential aspect of the training experience. This was interesting, particularly as the apprentices while being briefed on safety measures and procedures, there was a realisation that nothing could have prepared them for the experience of being there in person.

This finding partly contradicts the findings of Izard et al. (2018), who argued that extended reality technologies was a tool for education and training which could replace the utilisation of conventional training practices. Instead, this study found that extended reality technologies was unable to completely replace traditional welding equipment in a training session. Another limitation or challenge which was identified was the limited potential for realism in training welding when using extended reality technologies compared to traditional welding equipment, for example the learners criticised the shorter hands-on working area for the extended reality environment compared to a traditional welding training booth, which was also linked to the absence of being unable to handle and gain a level of competency in using the real equipment, therefore hampered the apprentice's gaining the necessary psychomotor skills, a theme highlighted as vital when learning how to weld by Jensen and Konradsen (2018) and Okimoto et al. (2015).

Linked to using the real equipment and resources, was that extended reality equipment was unable to show or reproduce the welding damage to the coupons when the apprentice moved the welding gun too slowly, or when they had the setting too high. These limitations potentially reduced the perceived effectiveness of learning to weld, and that safety-related issues were a key consideration and barrier for learning certain tasks or skills manually.

In continuing to address the first research objective, the findings indicated several opportunities for integrating extended reality training into welding education. The study's results suggested that extended reality technologies can assist the apprentices to acquire new welding skills, boosting their self-confidence and motivation, enabling the learner to practice crucial hand coordination and movement, while facilitating the learner to rehearse and practise the new skills more frequently. Chan, Haron, Isham, and Mohamed (2022) found evidence that training using

extended reality welding simulators could improve psychomotor skills including hand-eye skills coordination. Jensen and Konradsen (2018) in their literature review study attempted to update current knowledge about the use of head-mounted displays in education and training, which indicated that trainees' cognitive and psychomotor skills could be improved when using and utilising extended reality simulators for training. Associated with Jensen and Konradsen (2018) study, but directly related to welding training was the recognised benefit that extended reality welding simulators providing a relatively high degree of visibility, which allowed the learner to focus totally on the welding skills and techniques needed for learn the fundamentals.

As identified above while extended reality technology in welding training was unable to help the participants to understand the risks associated with this environment, the simulators did provide a risk-free training setting, which was devoid of gases, noise, and heat when the learner was practising on the virtual welding coupons. This finding was supported by Cai, Liu, Wang, Liu, and Liang (2021) and Cheng and Tsai (2012) who indicated that extended reality technologies potentially provided the participants with a virtual environment which could enable them to gain the necessary skills without the distractions associated with spot welding. Closely linked to this theme of being a conducive learning environment due to the removal of obstacles such as the heat and the noise, the extended reality learning equipment could be set up quickly and then adjusted to the learner's needs. This flexibility therefore enabled the learner to gain the fundamental knowledge associated with welding principles more effectively. The extended reality simulator also enabled both the learner and the instructor to track any mistakes in real-time, then permitted the trainee to analyse their technique and correct the error immediately without the complication associated with a traditional welding setting. The extended reality welding simulator also enabled each apprentice to create a profile that could document all welding training activities and show their performance and errors, which also enabled the instructor to track the learner's progression. This finding concurs with Huang, Lou, Cheng, and Chung (2020) and Da Dalto, Benus and Balet (2010) who stated that extended reality training simulator records can provide a personalised learning tool for both the learner and the instructor. The extended reality simulators also enabled the creation of a profile tool which enabled the trainers to remotely define, monitor and review welding exercises and allow them to review the individual learner's performance and progress. This finding confirms the study of Huang, Lou, Cheng, and Chung (2020) and Da Dalto, Benus and Balet (2010) who stated that an extended reality training simulator can enable records to be personalised with the apprentice's learning data, and that the learners can personalise their learning activities with the built-in database.

Finally, in addressing the first research objective, several participants in the study indicated that extended reality welding simulators enabled them as learners to overcome their initial fear of the traditional welding setting, which was documented during the first cycle of this study. For both learners and instructors, the welding simulators were seen to be more learner-friendly in acquiring the fundamental skills compared to traditional welding training methods. Reflecting this, the participants indicated that welding training should commence with extended reality welding simulators and then continue with the traditional welding training method. This strategy would therefore enable the learners to firstly acquire the fundamental skills by using the extended reality welding simulators, where they can learn and gain the essential skills and knowledge on the fundamentals of welding techniques before being trained on using the conventional welding equipment in a real-world environment. Not only can this approach speed up the training process, but the instructor can also assess each apprentice's progress and performance before they enter the potential hazards of the conventional training environment.

In achieving the **second research objective**: to study the student's learning experience when using extended reality technology to gain the necessary techniques to weld, the study found evidence as presented in Chapters Five and Six, that the apprentice learning experience was largely positive when using extended reality in vocational training and educational settings in the UAE.

As mentioned above, the benefits and opportunities of employing extended reality technology in welding training were highlighted by the learners in the focus groups. With the training being conducted in a virtual environment meant that the apprentices were initially able to gain the fundamental skills before being exposed to the real environment. extended reality enabled the learner to gain the required level of competencies without the associated welding risks such as being exposed to the sparks being generated, the noise of the electricity, heat, or gases, fumes, and radiation, which the apprentices encountered during the first training cycle of this study.

The extended reality simulators could assist the learner to be less concerned about the number of mistakes being made and the need for new materials needing to be provided. Linked to this was that the apprentices were able to identify and rectify their mistakes in real-time using extended reality welding simulators, which also provided live scores for each of the welding activities. The apprentices were also able to understand how to hold in principle the welding equipment while working under optimal light conditions. In analysing the performance data afterwards, the learners seemed to be more proficient and could repeat the same procedure and progress the welding tasks at their individual pace without impacting on other learners.

Moreover, with the use of the extended reality welding simulators, the ability to practice, gain feedback, and then re-practice allowed the learners to advance their skills and confidence to the level that they gain the fundamental skills and competencies potentially faster than the conventional modes of training.

Using extended reality enabled the apprentices to see how their virtual welding coupon was being welded, which was not possible in the traditional welding equipment due to the vision limitations associated with wearing the safety helmet which is a requirement to protect the eye against flashes of light. Such a positive experience of apprentices using extended reality was also outlined by Rusli et al. (2019), who noted that apprentices using extended reality as an alternative training methodology in welding can create a better experience compared to those using the traditional equipment.

Interestingly, many apprentices reportedly gamified their approach to learning to weld using extended reality and associated this with their experiences with games such as PlayStation. Related to this gamification aspect of extended reality was the healthy competitiveness which the researcher observed in the apprentices. Due to the recording of accuracy scores, the apprentices began to compete with one another. This can incentivise participation in the learning environment, with learners trying to achieve the highest score possible in the cohort, therefore promoting the learner to become self-motivated. This competitiveness therefore created a learning environment where all apprentices were highly engaged in the learning process. This increased participation was enhanced by the reduced waiting time to use the extended reality welding simulator, which was also a positive aspect of using this technological learning solution.

However, the study did reveal some limitations or apparent negative aspects to the learning experience when using this form of virtual or simulated environment as noted by Yilmaz (2016) and Yang, Chen and Tarng (2017). Although the apprentices when using extended reality had benefited from the lack of associated risks and hazards, such as heat, sparks and gases, the participants did not learn the necessary and fundamental safety awareness skills or where able to experience the real environment while in an educational setting. Consequently, the learners lacked the importance of how to deal with all the real risks surrounding welding operations. For this study, training with the extended reality simulators is not adequately on its own, as the technology is unable to replicate or expose the apprentices to the actual welding experience or the workshop environment.

While the study identified that the welding protective equipment was reportedly restrictive in terms of vision and weight, the apprentices when wearing the extended reality head-mounted display also referred to as head-mounted display (HMD), presented a different negative experience. The HMD weight due to the camera and the attached screen made the welding training helmets much heavier than the traditional welding headwear, which was compounded by the lack of reality, which was originally identified by McKnight et al. (2019) as a potential limitation. For some of the learners, the extended reality welding helmet was also restrictive as it was connected by a thick cable to the simulator, which caused restrictions on the learner's movement, which eventually led to discomfort while using the head-mounted display unit. While the helmet was heavier, the welding gun on the extended reality resource was seen as being lighter than the traditional welding equipment. This was because the traditional welding machine gun consisted of insulation materials designed around shielding the gas passage and the high-voltage electrodes, while the extended reality was simply a composition of cables needed for the data and power. This indicates that although extended reality welding simulators were seen as being like traditional welding equipment, they still lacked certain aspects of reality, a theme identified by Wells and Miller (2020), who found the equipment was not an exact replication. This lack of similarities also confused the apprentices and could potentially negatively impact on the overall learning experience if the technology was used in isolation.

In achieving the **third research objective** as to the instructor's experience when implementing extended reality technology in welding training, which was presented in Chapters Five and Six, the study showed that all instructors agreed that using extended reality welding simulators as being an exclusive method for training welders remains in its infancy and should be used to supplement the traditional method. The instructor's views included that extended reality have positive and negative outcomes on welding training. For example, several instructors noted that they could allocate more time to each apprentice group because the extended reality simulation group required relatively little supervision as there were no safety risks. This was in contrast compared to when using the traditional mode, where the instructors needed to pay attention to the apprentices who were practising welding. The instructors noted that due to the lack of noise in extended reality, it was easier to communicate with the apprentices compared to the traditional welding equipment training. The instructors could also provide real-time feedback to correct the apprentice when they might be making an error, as opposed to correcting the learner at the end of the task. This was further enhanced by the instructors being able to use the same screen as the apprentice while

monitoring their progression and skill development. This means of easy communication was further enhanced by the lack of distractions, such as the noise being generated from the welding equipment or the apprentice's being more aware of the gas and smells as opposed to listening to the instructions or feedback from the trainer. Finally, the instructors noted that the extended reality learning environment meant that there was no need to prepare or to set up the materials in advance and there was no wastage.

While there were clear benefits, the instructors also noted that learners still required actual hands-on exposure to welding and to practice how to mitigate the risks associated with conventional welding methods. The use of extended reality welding simulators has the potential to complement traditional hands-on training. The instructors stressed the need to combine extended reality with the actual welding experience, however the sequence of their usage was critical. By using extended reality welding simulators for practice, apprentices could learn the fundamental skills and techniques for welding without being exposed to the dangers associated with spot welding or having to wear the restrictive PPE. For the instructors, the study highlighted to them that combining extended reality technologies with more traditional welding solutions was the most effective way to teach trainees the fundamental welding skills and techniques.

Like the learners, the instructors also indicated that a blended approach which combines conventional welding training with extended reality welding simulators, may offer apprentices a more effective and comprehensive learning environment that provides a balance between gaining the fundamental of welding, before being introduced to the realities of safety and the environment. While this study indicates that the instructors were receptive to the idea of a mixed or hybrid approach in a vocational setting, Jensen and Konradsen (2018) and earlier by Huang, Laiw and Lai (2016) found that most extended reality applications for education are designed to be run independently. Also, that extended reality was designed to be used in a traditional learning environment as opposed to a vocational setting.

Finally, in meeting the **fourth research objective**, this study will present a series of related recommendations which has emerged from the real data generated as to the opportunities and challenges associated with implementing extended reality in a vocational welding setting in the UAE. This study found that there were several challenges associated with training using traditional welding equipment as identified in Chapter Five, then discussed in Chapter Six. To emerge from the study was the associated challenges with training in a welding environment, like the poor ventilation in the workshop and the equipment used. The poor ventilation led to

some of the learners and the instructors' experiencing some discomfort due to the heat and the fumes. The discomfort was increased due to the need to wear the statutory PPE, which increased the discomfort experienced by the apprentices. The PPE was reportedly highly restrictive, with the helmet offering limited visibility and a lack of air circulation.

This was not only experienced by the learners, as the instructors were also required to wear PPE including a welding helmet, therefore experienced the same issues of low visibility, which prevented the instructor from effectively monitoring, assessing, and evaluating the progress of the learner, while also being in discomfort due to the lack of ventilation. While poor ventilation and the usage of PPE was recognised as the norm for welding, therefore could not be eliminated, in a training environment, the issue of low visibility and poor ventilation could be reduced in the early stages of the training programme using extended reality technology, as the requirement to wear restrictive PPE was not needed when using the simulator. This is aligned to Agrawal and Pillai's (2020) assertion that conventional welding does present the dilemma of needing to provide the learner with the correct safety equipment and the need for them to become accustomed to the working environment, while also enabling the learner to learn effectively.

Another challenge identified during this study was how the learners attained and then were able to practice their hand to eye coordination skills and hand stability, which proved to be difficult when using the actual welding equipment. Linked to this, was the number of attempts needed to perfect the learner's level of proficiency, which led to a high level of wastage of welding coupons. During the focus groups, the learners reported that they felt a pressure to learn how to keep their hands steady during welding and to achieve the accuracy rates quickly, as there was a perceived cost implication. This was further compounded by the environment which included sparks and the noise of the electricity, which proved to be a distraction to the learner, and also the lack of opportunity to practice and rehearse their skills. This study also found there was a long wait time for the learner to wait, as the instructor needed to prepare the welding equipment. For the instructor, the traditional welding resources often needed to be re-calibrated and coupons to be prepared so that the learner could practice. During this time, the calibrated process meant that the instructor was preoccupied in resetting the equipment, but while this was happening the trainer was unable to engage with the learner, which led to the apprentices tending to be disengaged, potentially reducing the effectiveness of the training program. Time was also lost as each learner had to patiently wait their turn, which again led to significant level of disengagement amongst the learners.

Overcome these challenges associated with welding, the next section will present the contribution to knowledge and practice. One of the key recommendations is that the initial vocational welding training should commence with the usage of extended reality technologies. In following this strategy, the recommendation is to adopt a hybrid model or solution. While using this hybrid approach, the recommendation is to introduce the learner to welding using the extended reality technologies. This would permit the learner to gain the fundamental skills including learning the basic hand-eye coordination skills while getting used to handling the welding gun. The strategy would also mean that the learner would not be exposed or distracted by the heat, noise, and smells generated and the need for restrictive safety procedures to be followed. However, the recommendation is that once the trainee has gained the fundamental techniques and skills, the learner needs to then be exposed and become familiar with the actual equipment, resources, and environment.

8.5 Contribution to the academic knowledge

This section will outline the contribution of this study to existing knowledge (e.g., Izard et al., 2018; Maresky et al., 2019; Seagull, Moses, & Park, 2008; Jenson & Konradsen, 2018) as to the debate about vocational training usage of traditional welding techniques compared to extended reality technology. The section will commence by setting out the contribution to academic understanding of the challenges associated with training apprentices when using conventional welding equipment. The evidence presented in the previous chapters, Chapters Five and Six, have illustrated the challenges associated with training using conventional welding equipment, however, there remains limited academic research (e.g., Okimoto, Okimoto & Goldbach, 2015; Stone, McLaurin Zhong & Watts, 2013; Papakostas, Troussas, Krouska & Sgouropoulou, 2022) into this area of study. The section will then proceed to set out how extended reality welding simulators can potentially enhance the welding training experience for the learner. From the existing literature as presented in Chapter Two, there was a notable lack of research as to how to implement extended reality technologies in a vocational training setting (e.g., Maresky et al., 2019; Corter et al., 2007; Gennrich et al., 2018), including in the UAE, and in terms of its application in welding training per se. This section will also address the gap identified by Okimoto, Okimoto and Goldbach (2015), who highlighted the need for further longitudinal research to be conducted into utilising of extended reality technology in welding training particularly as to whether the learner accepted this form of technology to be trained on. This paper has attempted to address this gap of Okimoto, Okimoto and Goldbach (2015), by focusing on the long-term exposure to this

technology when used to train apprentices in basic welding techniques, but from a UAE context.

Finally, throughout the literature review there was an acknowledgement of the limited research conducted which addressed the effectiveness of applying extended reality education to a multi-age vocational group. This study through intervening in TVET based in the UAE, and specifically focused on welding education has enabled the study to capture the experiences of the apprentice learners and instructors experience of this technology compared too, and then combined with, the more traditional mode of learning. While there exists academic debate as to the usage of VR/ XR technology, for some writers such as Chikarkova (2018), there has been a perception that extended reality and related immersive technology are seen as being a trend, and therefore have been dismissed as a gimmick. This study challenges this perspective and has provided empirical evidence to contend that technology available today can bring apprentices in touch with sophisticated equipment, solve issues and assist them in learning.

By applying contemporary extended reality technologies into the domain of technical education, this study contends that vocational education, including in the UAE can benefit from these technological solutions, however this research does also acknowledge that technology is not a like-for-like replacement for traditional vocational learning. In this study, the use of extended reality technology in weld training does offer a new learning experience and environment which can enable the learners to engage more actively in the welding activity, as opposed to being constrained, restricted, or distracted from learning the essential skills. This finding therefore adds to the existing academic knowledge related to extended reality technology usage in a vocational educational setting (e.g., Maresky et al., 2019; Okimoto, Okimoto & Goldbach 2015) and challenges (Feier & Banciu, 2021).

One of the primary gaps identified in the literature review was that there was limited research (e.g., Okimoto, Okimoto & Goldbach 2015), as to presenting the benefits, limitations and challenges associated with adopting extended reality in teaching welding. This present study has attempted to bridge this gap by setting out the current challenges associated with welding training using both traditional learning and then technology-based methodologies. In addressing this identified gap, this study found that the learners' psychomotor skills were improved and benefited from being exposed to extended reality technological solutions, through the experiences of the learners captured in the focus groups, together with the

observed improvements of the apprentices by both the instructors and researcher as to hand-eye coordination skills, which are essential for welding.

The final academic contribution of this study has been associated with the current debate and acknowledgement that training welding can be problematic due to the associated challenges including the environment and the equipment used (e.g., McKnight et al., 2019; Johnson, Khan & Ophoff, 2019; Bonner & Reinders, 2018). This theme while being extensively researched over the years (e.g., Jerald, 2016; Jensen & Konradsen, 2018), which led to Lee et al. (2022) to contend that welding training is often hindered or hampered by the welding workshop. This study unlike Lee et al. (2022) has shifted the academic focus by adding a new dimension to the current debate, by contending that the learner can gain the necessary and fundamental skills in a more learner friendly environment. This finding adds a new dimension to training apprentices to weld by advocating the inclusion of a hybrid solution, which could commence with the usage of extended reality technology, before the learner is exposed to the real authentic welding equipment and environment.

The present research also provides a substantial academic contribution to understanding the influence of extended reality training in various technical fields and not only teaching apprentices how to weld, but from a UAE perspective. Currently, in the UAEs vocational education there is a substantial gap of knowledge as to how to effectively educate this type of apprentice. To address this, this study has attempted to bridge this gap of academic understanding by firstly providing an interventionist perspective as to the theme of implementing extended reality technology into a vocational welding programme, and then through adopting a social constructivist perspective, to gather in-depth information related to the learners' and instructors' perspectives. Then through adopting an interpretative approach the interview data was analysed to provide a rich insight into how training apprentice welding training in the UAE should be conducted. For the UAE apprentices based in the TVET, and in other locations both in the Middle East and globally, extended reality can positively enhance welding training and other technical training courses, but there was also a need to ensure that the traditional mode of learning experience needs to still be provided.

Unlike previous academic studies including Jensen and Konradsen (2018) that there has been an omission of capturing the learner's actual learning experience, therefore this study has attempted to address this. This study has expanded on the theme of whether the apprentice can gain the necessary skills learnt and acquired through a virtual learning environment, and if the emergence of gaming technology has been beneficial. Reflecting the earlier research of

Lavrentieva et al. (2020) and Stone et al. (2011) who have noted that due to the familiarity of this sort of technology, learners are able to become more proficient in performing certain tasks compared to those following the traditional means to learn. However, this study does also partly contradict the same studies, as the research needed to be extended to include a hybrid solution to incorporate a technological and traditional solution, as there were significant weaknesses identified, including the lack of authenticity of the real welding experience.

8.6 Contribution to Practice

Building on above, the next section is dedicated to presenting the contribution to business practice, which is the focus of this professional doctorate. This section will focus on the practical contribution of the study, by presenting how the learner, the instructor and the sector can benefit from a hybrid solution of using traditional training practices combined with extended reality technologies, which includes potential behavioural changes. The section will commence with how this technology can assist in adult vocational education.

8.6.1 Integration of advanced technology in adult vocational education

Technology in education has the potential to be one of the most valuable methodologies for assisting the learner in acquiring specific vocational skills (Gonzalez et al., 2018). To date, as presented in Chapter Two, the integration of advanced technology for adult training, has been focused specifically on using ICT in a formal educational setting and with limited research as to its application in vocational training, and even less on its usage to train apprentices to weld. Therefore, this study has identified that there is an existing gap into investigating the usage of extended reality -based applications for training adult in a vocational setting, but from an UAE perspective. In addressing this gap, this study has identified that using advanced technology in a vocational educational setting can potentially be beneficial, but has also possible limitations, which challenges the assumption that extended reality can replace traditional vocational training, as advocated by Hamid, Waycott, Kurnia and Chang (2016).

This study through conducting an interventionist approach to generate real outcomes in a vocational training setting has identified that extended reality can potentially improve vocational practice enabling the adult learner to practice then acquire the necessary skill sets in a ‘safe’ environment; however extended reality needs to be combined or integrated with traditional training methods. The premise of this conclusion is that while extended reality offers significant benefits which includes a learning environment where the distractions of the

welding workshop setting is removed, including the gases, smells, noise, and the heat, it also needs the reality of the welding setting. Using extended reality therefore enables the learner to acquire the fundamental skills, before then being introduced to the real-life setting of welding to advance their skills and experience, hence this study advocates a hybrid integration of extended reality and traditional training practices, and not to simply use one training approach in isolation.

8.6.2 Improving the time efficiency to acquire the necessary vocational skills

This study has shown that with the use of extended reality in vocational education to train learners in welding can lead to reduced time needed for the apprentice to acquire the basic vocational skills. The interventionist findings showed that both the apprentices and the instructors indicated that the time required for training was significantly reduced when extended reality technologies were used compared to training using the actual welding equipment (Cabero-Almenara, Fernández-Batanero, & Barroso (2019). This theme of time efficiency for the learner to gain the necessary skills, led to the apprentices to firstly gain and attain the fundamental skills, but also additional time to reinforce their newly acquired skills by continually practicing them.

This study found that utilising extended reality in a welding setting can reduce training downtime compared to the traditional training method, which includes the time needed for preparation of resources and materials needed to be completed before each practice session commences. Instead, the extended reality welding simulator permitted the trainees to have more hands-on training practice to learn the fundamental welding skills in a virtual setting, where no preparation is needed compared to the traditional training method. The study also found that the actual time required to train apprentices to become proficient in the necessary skills could be substantially reduced, while also enabling the learner additional time to practice these new techniques, like the insights provided by Papakostas et al. (2022). The outcome of these findings demonstrated that more apprentices gain the necessary skills and could be ready to enter the workforce in a shorter duration, potentially addressing the current shortage of welders in the UAE.

8.6.3 Improved learning outcomes for the apprentices

In this study, using extended reality to teach welding can potentially lead to improvements in learning outcomes of the apprentices. Through using extended reality, the trainee welders were able to gain the basic techniques without the distractions of the real environment

(Chankhwar, Chuang, Tsai, & Smith, 2022). This lack of distractions including the heat, smell, and associated noise led to the learners to focus on the task in hand, and then to practice this skill to reinforce the techniques learnt. From the evidence of this study, the findings indicated that using extended reality enabled the apprentices to gain the confidence which enhance their motivations and ability to acquire the new welding techniques, improve their psychomotor skills, and without needing also to overcome their initial fears of the heat, electricity, radiation, and sparks being generated which were also discussed by Shankhwar, Chuang, Tsai and Smith (2022). Part of the benefits could be associated with the learners being more engaged in the learning experience while using extended reality, as it matched their gamified mindsets, which brought in a competitive element to the overall learning experience. However, as previously mentioned, the usage of extended reality should be seen as not being the complete solution, instead this study contends that the traditional welding setting and associated environment is still unable to be replicated in a virtual environment, therefore there is still a need the apprentice to be exposed to a traditional welding setting (Oztemel & Gursev, 2018).

8.6.4 Improved learning outcomes for educators

Through adopting an interventionist research strategy, this study enabled the vocational training instructors to modify their existing welding courses to include the traditional training methodology then the usage of the extended reality resources to ascertain which was the most effective way of enabling apprentices to become proficient in welding (Asplund & Kilbrink, 2020). The findings indicated that the instructors using extended reality were able to monitor the learner's progress in real-time and engage with the learner as they learnt and practiced the various techniques, something which was not possible using the conventional welding training method, due to distraction of sparks, and loud noises generated. The usage of extended reality enabled the welding instructors to in monitor in real-time the progress of the apprentice on the extended reality screen as the apprentice practiced their welding techniques. This enabled the instructors to advise, guide and correct any apprentice's mistakes in real-time. The outcome of this finding, indicates that the usage of extended reality can benefit vocational training of welding at the UAE technical training school, enabling the learner to acquire the necessary skills before progressing on to experience the real environment under direct guidance of the instructor.

8.6.5 Improvements to the vocational learning experience

Through conducting this interventionist project, the findings indicated that the apprentices gained the necessary skills faster using the extended reality technology and then honed their techniques with the conventional welding tools. These results are confirmed by the study of Okimoto, Okimoto and Goldbach (2015) who found that the use of XR technology in welding practice was a major advantage for learners as it enabled them to gain the necessary welding skills in a more secure environment.

This finding potentially means that the usage of extended reality combined with the actual welding resources can enable the learner to gain the necessary vocational skills and could be potentially applied beyond the training school environment of welding and be applied to other vocational training settings and "on-the-job training" methodologies, which has also been argued by Rusli, Zulkifli, Bin Saad, and Yussop (2019) that the XR technology can be used more widely in technical and vocational education and training because it combines both theoretical and practical learning.

This study contends that the welding sector, with the intervention of extended reality technologies can provide a cost-effective solution to training the learner in the basic techniques, without the costs associated with the practice materials and time needed for setting up the resources. Once the learners have gained the fundamental skills, then the trainee can practice on the real equipment, and then practice and weld using the actual materials. Through adopting this strategy, this study contends that the current shortage of skilled welders in the United Arab Emirates which is acknowledged to be a critical concern in the sector (Shankhwar et al., 2022), can be potentially addressed by preparing qualified welders in a shorter period of time.

8.6.6 Improvements to the behavioural skills of learners and instructors

During the study, several behavioural changes were observed and identified during the interviews, the focus groups and by the researcher. In the focus groups the apprentices identified that the new approach to a hybrid training concept potentially helped them to overcome their initial fears when starting to learn how to weld. The focus group session, particularly cycle one indicated that the risks and hazards of sparks and electricity associated with welding adversely affected their performance in learning the fundamental skills. This was a challenge identified by Lambardi et al. (2005, 2009), who noted that the PPE and the

sparks generated can inhibit the learning experience. However, with XR technology, the learners were able to concentrate on gaining the basic techniques, as opposed to being aware of the external environment, which became a barrier and a distraction.

In cycle two and then in cycle three, the apprentice's attitude and willingness to learn was also influenced by their familiarity of XR technology. This recognized familiarity led to the emergence of an almost competitive behavioural change amongst the apprentices which potentially gamified the training experience, which resulted in the apprentices becoming more engaged and motivated to learn how to weld, which was advocated by Smith (2019), Pottle (2019) and Lavrentieva et al. (2020), who highlighted the benefits of XR technology, but from an extended reality perspective only. Earlier, Ero et al. (2016) noted that technology has begun to enable digitalization of manufacturing and associated training activities, which has enabled the learner to improve their cognitive skills without the restriction of the workplace environment. Through conducting the interventionist project, the study inclusion of XR technology made the learning environment to become for the learner more competitive, exciting, and generated a sense of fun during the training session. Part of this was due to the challenge of achieving a higher score compared to their fellow learners. This was only achieved through the means of technology and the ability to provide real-time feedback to the apprentice's progress. This led to the learners changing their behavioural attitudes to learning from being needing to learn, to one of wanting to learn. This behavioural change then continued when the apprentices finally used the traditional welding equipment, as the competitiveness and positive attitude of wanting to learn using the actual resources continued.

With the use of XR technology, the learners were able to monitor their progress not via the instructor, but from the simulator. As a result, the learner was able to gain perceived objective and independent advice and guidance, as opposed from only the instructor. This independent objective advice led to the apprentices being more receptive to future guidance, particularly from the instructor, which Huang et al. (2020) and Da Dalto, Benus, and Balet (2010) found that the XR technology can provide objective reliable feedback. Both the instructors from the one-to-one semi-structured interviews and the learners focus groups indicated that there was a behavioural change as to the acceptance and willingness to listen and reflect on guidance and criticism.

For the instructors, XR technology changed the instructors from being simply an 'instructor' to taking a more 'facilitator' role. This change of role permitted and enable the instructors to be more relaxed and not needing to constantly be concerned about the apprentice's safety in a

real welding environment due to the associated hazards. The instructors also highlighted that the learning environment was more manageable, which permitted them to spend more time going around assisting learners, as opposed to teaching the learner on an individual basis. The instructor's behaviour changed from one, often expressing frustration as the learner could only be trained on a one-to-one basis, which resulted in the apprentices being often disengaged, with some chatting, playing around, or constantly using their phone when in the traditional training sessions, to one more being engaged, a theme identified by Okimoto et al. (2015) as being a potential barrier which XR technology can address. The XR simulators also reduced the instructor's concern about limited training consumables, and their need to balance costs against enabling the learners the opportunity to practice. With the usage of XR technology, the instructor's behaviour changed to become more focused on the entire cohort of learners to learn the fundamentals skills before proceeding onto using the real equipment.

8.7 Limitations of the Study

There were several limitations associated with this interventionist study. The first limitation is the potential bias of the researcher, as the action research project used a social constructivist approach. As a social constructivist project, the study was designed to conduct a series of focus group interviews with the apprentice learners and then one-to-one interviews with the instructors, from which the data was analysed using an interpretivist approach, which meant that the researcher needed to ensure that the subjective bias of interpretation was minimised. To address this potential bias, the researcher needed to confirm that the interview data was captured and transcribed accurately to achieve trustworthiness, dependability, and authenticity. The researcher then checked the transcripts several times during the analysis step to ensure that the participants' voices were appropriately portrayed. The second bias was related with the researcher's affiliation with the training school, as he was a member of the welding faculty. To overcome this, the researcher remained an outsider throughout the study and delegated training responsibility to independent instructors. However, because the whole methodology was qualitative, these biases were handled very maturely based on the viewpoint of the intended audiences and neglecting any externality of the researcher's experiences. This helped in relying on and understanding the data gathered by the interviews in order to satisfy the study's aims and objectives.

The next limitation is associated with the sample size. This research followed an interpretivist approach using an action research method to conduct three intervention cycles. To achieve this, and because the study was grounded in a subjective perspective, the sample size was

small. This was also due to the cohort size of learners and available instructors. Part of the reason for the relatively small size of the participants can be linked to the COVID-19 pandemic. As this study was conducted during the outset of the pandemic, the UAE implemented strict socialising and group policies, which influenced the number of apprentices participating. These limitations included downsizing the number of apprentices enrolled in any class to twelve learners at one facility. Recognising this small sample size, the study focused on providing a rich insight into the experiences of learning how to weld using traditional and extended reality equipment, as opposed to providing a generalised outcome. Furthermore, a generalised inference was not the intended outcome of this study, but rather to generate real data and bring about a potential change and transformation in how to train apprentices in welding. The outcome of this strategy has been the extensive presentation of the findings, which illustrates the longitudinal and development aspect and nature of the study.

This study also recognises that collecting the data through focus groups has its own limitation. With a focus group often, the voices of participants can be missed, not heard, or not declared due to the complexities and dynamics of the group a theme acknowledged and identified by writers such as Bryman (2019). To overcome this, each participant was asked to respect each other and their point of view. Each participant was given an opportunity to speak and express their experiences. However, the use of the focus group enabled the participants to share their experiences and the format generated new ideas, which may have been missed if the study was conducted individually using semi-structured interviews, like for the instructors.

8.8 Areas for future research

The main recommendation for future research is to extend the action cycles to evaluate the long-term effects of extended reality technology in welding education which has also been discussed by Lavrentieva, Kuchma and Skripnik (2020), then to investigate the impact of extended reality technology on the learner's long-term skill development. Linked to this, recommended is that future research could adopt a mixed method approach to capture the experiences and then to evaluate the learner's performance.

Another area for further research would be to investigate the potential benefits and challenges of the extended reality technologies on other types of welding methods which has also been discussed by Zenisek, Wild and Wolfartsberger (2021), such as those of inert metal gas, stick

welding, inert tungsten gas welding, gas tungsten arc welding, gas welding, metal active gas welding and flux cored arc welding, to evaluate the effects of applying these welding techniques in using an extended reality technology in vocational educational setting.

8.9 Concluding Reflection

In hindsight, this research project was not a straightforward journey. Originally, the intention of the study was to understand how welding training could be improved to permit the learner to improve and hone their skills in a safe environment, but with the intention to prove that extended reality could be a positive experience, through conducting an interventionist research. Rather than trying to conduct a generalized outcome or to simply generate a new theory, the study's focus shifted to make real changes in a vocational educational setting and provide evidence of changes to business practice, a key facet of a professional doctorate. In achieving this, this paper's contribution has included the demonstration that the use of extended reality in professional welding education could potentially enhance vocational education, particularly when training individuals to weld. Using extended reality particularly psychomotor and behavioural skills can be enhanced and developed, as the workshop environment is removed from the initial learning experience. With extended reality, the learners are given more time to learn the fundamental skills of welding but in a cost-effective manner, as opposed to being constrained by the instructor's availability of needing to supervise individual apprentices and also be restricted by available resources to practice.

This research has potentially assisted the technical training school provision of teaching apprentices in the UAE as to how to gain the fundamentals of welding techniques through conducting an interventionist approach to generate real or active outcomes, by bringing about change in a vocational technical setting. To emerge from the study was the benefit from the hybrid approach adopted which made the training process more efficient, improved the learner's experience and attitude to learn and greatly reduced the waste of resources and time for both the apprentices and the instructors. Through the incorporation of a hybrid XR and traditional welding methodologies, the associated hazards of the workshops and teaching environment which can impede or have a negative effect for the learners and instructors' behaviour, while also minimizing injuries and associated accidents occurring when first learning how to weld. Therefore, through adopting an interventionist approach, the study has potentially helped the technical training school to achieve a safer learning environment in the training of welding skills, including how to control weld equipment, before experiencing the real environment. This research also can be expanded and inform other United Arab Emirates training schools as to the potential of using this technology in other vocational course settings to enhance their curricula.

While the current research has clarified and understood the efficacy of incorporating extended reality technology into welding training in the UAE, there is a need to identify factors that encourage a willingness to use this technology in vocational education transfer in the UAE context.

Overall, this research journey was complex and had many challenges for me in the beginning, as I faced notable challenges in conducting practical research for many factors, the most important of which was how to start the doctoral program after a long time from my previous academic study in master's degree, which was almost 12 years. The other challenge was how to focus and select the right research topic that would help the technical education sector in UAE. In addition to the fact that reading and writing in an academic manner frequently made me feel bored when I began to read, there were moments when I could not comprehend what I was experiencing with the new technology of extended reality reading. I first had difficulty meeting my daily reading goals.

Nonetheless, when I was reading the latest extended reality technologies articles and news from a scientific peer, and read journals for my research and to be updated from time to time; I found this is essential as it will allow me to develop my research skills and educate me on how to use the latest technology in technical education that is a trend now and have great future potentials in different industries, occasionally, When I miss reading in any day, I eventually try to make it up and read four to five hours on the weekend. Although my first slow-paced reading was at the beginning of my DBA journey, it was such exciting and joyful technologies not only in education but in other fields too.

Also, one of the challenges I found very hard was searching the literature as it was time consuming, therefore frustrating sometimes, tedious, but did have exciting moments of real discovery. I found some of the literature hard to understand and received information that held short interest to me and in other circumstances. Moreover, masses of journals, articles, books, and lists of websites started to become systems of classifying and reviewing details and were refined or rejected. There occurred many times when the literature surrounded me, and uncertainty dominated as the opportunities for research began to multiply.

Choosing the suitable methodology took much work for me at the beginning as I thought of following the quantitative approach of positivism in my research, as I always believe in numbers and quantitative data to ensure validity and reliability. I thought of mixed method research till lastly and based on the objectives of my research and the change that I was

seeking to do in the technical welding training, I found that intervention or action research was the best-fit approach to achieve the research aim and objectives.

Another challenge was the start of the welding training course, as my research required conducting an actual course and doing the changes in different action cycles, which it has challenged due to the challenges of recruiting the participants and conducting the welding course with the circumstances of COVID-19.

Finally, the last challenge was how to avoid researcher bias that could affect the reliability of the research. My concern was that bias in any research could happen intentionally or unintentionally. Causes false conclusions and will potentially misguide the outcome of the research. A doctorate is a journey and one that changes people. Reflecting on the start of my journey and comparing my thinking, thoughts, and beliefs to now, I am a different person with a new academic identity. In the beginning, I was not aware of the broadness and depth of understanding that I was progressing to increase and the scale of hard work that reshaped me in gaining such an understanding of and experience, and it changed my belief and perceptions of the doctoral research is not the end it is just the start.

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Appendices

Appendix A: Informed Consent

The potential of extended reality in welding training in the UAE – opportunities and challenges

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Introduction and Purpose of the Study
The study aims to develop an understanding of the current vocational welding training in the UAE and to develop a comprehensive which is focused on investigating the potential of using XR technologies in welding training apprentices in the UAE.

Description of the Study
All the participants will be enrolled in a welding training that will adapt different training cycles. All participants of this study, will be asked a set of open-ended questions regarding the welding training experience.

Research Commitment
The interview will be scheduled to reflect your commitments. The interview will take place at a neutral and discrete location (chosen by the participant), and will last between 1 to 1.5 hour.

Confidentiality
All private and contact information will be treated confidentially, stored safely, and will not be shared by any third party.
All the data will be aggregated and analyzed together, ensuring that individual participant identity is anonymized.

Voluntary Participation
Participating in the study is totally voluntary.

Benefits for Participating
Your participation will contribute a great help in developing and enhancing the UAE vocational welding training by using Extended Reality technologies that will benefit vocational and welding industry and the UAE.

I have read the above details and give my voluntary consent to participate in this research study
□ Yes □ No

Name of Participant:

Signature of Participant: Date:

Person Obtaining Consent:

Signature: Date:

Appendix B: Interview Questions for the focused group

1st Cycle Interview questions (open-ended questions)

1. How do you find the training with traditional welding machines only?

1. What were the benefits you gained from the training with the traditional welding machines?
2. Why do you find it beneficial?
3. What were the challenges you faced with the training by the typical welding machines?
4. Why did you find it challenging?
5. Was the training interesting?
6. Why?
7. Do you think it was easy to perform the required tasks during the training with welding machines?

2nd Cycle Interview questions (open-ended questions)

1. How do you find the training with AR/VR welding simulators only?

1. What were the benefits you gained from the training with AR/VR welding simulators?
2. Why do you find it beneficial?
3. What were the challenges you faced with the training by the typical welding machines?
4. Why did you find it challenging?
5. Was the training interesting?
6. Why?
7. Do you think it was easy to perform the required tasks during the training with the AR simulator?
8. Do you think the AR simulator was a more effective tool for teaching welding procedures than real practical training? Why?

3rd Cycle Interview questions (open-ended questions)

1. How do you find the training with AR/VR welding simulators and the real welding machines?

1. What were the benefits you gained from the training with AR/VR welding simulators AND the real welding machines?
2. Why do you find it beneficial?
3. What were the challenges you faced with AR/VR welding simulators' training and the real welding machines?
4. Why did you find it challenging?
5. Was the training interesting?
6. Why?
7. Do you think it was easy to perform the required tasks during the training with the AR simulator?
8. Do you think the AR simulator was a more effective tool for teaching welding procedures than real practical training? Why?
9. To what extent has AR Welding Simulator helped prepare you for practical sessions?

Appendix C: Interview questions for instructors

1. How did you find the experience of training with virtual reality technology a traditional welding methods?

2. What challenges did you face as a welding instructor?

3. How was the communication with the students during the last training cycle?

4. Was the training in the third cycle (Hybrid training) better than the firs and the second cycles? and Why?

5. What are the challenges that you faced during the training welding in the first and second cycles?

6. Why do you think combining VR and AR technology with the traditional welding machines in training will change welding in the training school?

7. How would you describe the experience of a welding instructor using the VR and AR technology with the traditional welding training methods?

Appendix D: Final coding structure with themes:

	Themes	Codes	Codes N.O
Cycle 1	Theme One: The benefits of traditional vocational training	Skills: Traditional welding enables the learner to actually control the welding resources, for example, using the real gas welding to re-calibrate the equipment	1.1
		Skills: Real welding is beneficial as it is very interactive	1.2
		Skills: Real welding teaches the user about safety and security	1.3
		Equipment: Welding with real machine requires a progression of skills and knowledge	1.4
	Theme Two: Challenges of Traditional Welding	Environment: poor ventilation in the workshop made it hard to work long	2.1
		Perceptions of the task: Students have lack of confidence in using welding equipment	2.2
		Perceptions of the task: Traditional welding is very time-consuming, particularly as to waiting	2.3
		Perceptions of the task: need for more practice-time	2.4
		Perceptions of the task and equipment: visibility is an issue in traditional welding with the safety gear	2.5
		Equipment: re-calibration of the actual equipment was challenging	2.6
Cycle 2	Theme Three: Virtual training (XR) can assist as an intermediate training tool	Perception of the task: XR can help save materials and time	3.1
		Perception of the task: XR technology may help in gaining basic skills before real welding	32
		Perception of the task: XR training can remove the fear of heat for the students	33
		Perception of the task A standardised process is necessary for XR	3.4
	Theme Four: XR can help impart necessary skills	Perception of the task: XR can help with hand stability	4.1
		Perception of the task: XR can be used for fine-tuning skills	4.2
		Perception of the task: XR can help if the time available for training is short	4.3
		Perception of the task: XR skills translate into real-world skills	4.4
	Theme Five: XR training can be provided first, followed by traditional training	Perception of the task: XR or VR allow to track mistakes and assist in correcting them	5.1
		Perception of the training sequence: Better to start with XR first, followed by traditional	5.2
		Perception of the task: XR can help with overcoming the fear of welding	5.3
		Perception of the task: Gained more skill in XR	5.4
	Theme Six: XR cannot replace real-world training	Equipment: A smaller area in XR compared to traditional	6.1
		Perception of the task: XR cannot accurately re-create the reality of the working environment	6.2
		Equipment: XR requires a background in computer	6.3
Cycle 3	Theme Seven: Combined training is superior	Perception of the training sequence: Combining XR and traditional training have significant benefits	7.1
		Perception of the training sequence: Combined XR and traditional was beneficial than a single merthod	7.2
		Equipment: Combined training saves time and resources while all participants are engaged.	7.3
	Theme Eight: Better skill development in combined training	Perception of the task: XR helps overcome the fear of welding, but in the same environment	8.1
		Perception of the task: Providing more confidence when transitioning from XR to	8.2
	Theme Nine: Suggestions for further improvement	Perception of the task: Need to try and emulate or replicate the real welding experience	9
	Experiences of the Instructor	Equipment: No difficulty in training with combined XR and traditional	10.1
		Training experience: More control over the students	10.2
		Training experience: Seamless training experience using XR	10.3
		Equipment: Safety control is more efficient with XR	10.4
		Training experience: Better communication of errors in XR compared to traditional welding	10.5
		Training experience and equipment: Combined was better than single of delivery	10.6
		Training experience: Starting with XR is a good option	10.7
		Training experience: Real-time rectification of mistakes and errors	10.8
		Equipment: The need to emulate or replicate the real welding	10.9
		Training experience and equipment: Instructors can evaluate the performance of students post-traini	10.1
		Equipment: XR (AR/VR) technology welding training devices offers mobility of the training services	10.11

Appendix E: Focused group Cycle 1 Codes and Transcripts (Traditional Training)

	Codes	Direct Quotes from Participants	Participants
TH1	1.1 Skills: Traditional welding enables the learner to actually control the welding resources, for example, using the real gas welding to re-calibrate the equipment	A good experience that benefited us in practice,and we know how to control the machine? How? We use the nozzles, we learned how to control the gas, the type of gas. we also learned how to use the right thickness of the wire, as the teacher said	4
		It is preferred to start with a thinner wire gauge then once we get more confident, we can increase the thickness little by little to achieve optimum results	9
	1.2 Skills: Real welding is beneficial as it is very interactive	As for the training, the training was excellent and very good because all the students interacted with the training and they were .. I mean happy with it and the instructor did not spare any effort to provide the good training for us. It was a very wonderful experience for us. I mean, those who do not know welding begin to learn.	4
		The students and I enjoyed the experience and it was good. Some students struggled with their first time in welding and need to practice more just like someone training on target shooting	9
	1.3 Skills: Real welding teaches the user about safety and security	the danger of using the same machine without taking, for example, the contexts of safety and security or safety itself	6
		It is possible that the safety equipment and helmets are old; for example, the ones we used with the colleagues were old, and the vision was not clear. *I mean, the whole group suffered from using the same thing. As well as exposure to the risk of*	8
	1.3 Equipment: Welding with real machine requires a progression of skills and knowledge	Of course, in the beginning, it is impossible for anything new to be easy. It must be difficult. I mean, especially during an attempt. This may be a little difficult at first, but it will be easy with repetition, and it will be a little easier. But it was	9
		at the beginning, as new students, is the first time we use the device. This is sure that we encountered problems, how to use it, how to deal with the dangers of this device in general, from electric current or from heat emitted from the work period	7
		In the beginning, it was difficult, especially as a first-time user. But with practice, I began to improve. I believe I need more training on the VR/AR simulation to improve my skills	12
		The pleasure is in using the same machine and identifying how to use it and gain good valuable knowledge while also having fun. I learned something new and interesting that could benefit me in my practical and personal life	6
TH2	2.1 Environment: poor ventilation in the workshop made it hard to work long	Providing a means of ventilation because of fumes and gases, at the time of work, the gases were coming out, but I have no knowledge of whether there are toxic or non-toxic gases. It is preferable to have ventilation close to the location of the wo	7
		"Yes, and yet there is something in the workshop, poor air-conditioning and ventilation".	4
	2.2 Perceptions of the task: Students have lack of confidence in using welding equipment	*Due to lack of confidence, doubt is generated. For example, how can he weld or how he uses it, how can he connect two pieces at the beginning of the first use*	6
		The first time in my life, I held a welding machine. I mean, the first thing when I saw the spark, I was afraid of it because I thought it would burn me when it started hitting me; this was in the first time. However, the second time, I began to get used to it and know how to deal with it	8
		Honestly, this was a special experience; I broke my fear because I also fear electricity. Afraid of the sound of electricity. My first problem was how I would deal with my fears of electricity and sparks. However, I faced my fears when I started training with real welding equipment, and I started to know how to deal with it	5
	2.3 Perceptions of the task: Traditional welding is very time-consuming, particularly as to waiting	*Also, the few numbers of machines, for example, if we have a course with 20 students, then we need to have many machines running at the same time, and we experienced delays and waiting time because the first thing you start to practice welding is the straight line in a metal, so this would consume much time, and each student needs at least seven minutes to 8 minutes or sometimes even 10 minutes per pass*	9
		The first issue with real welding is that it takes much time to adjust the device and work on the welding machine to eliminate the issues in the settings. For example, we are supposed to start from 8:30, meaning the coach must be there at 8:00. We start welding. The first one is welded at 9:50 on the first day, right, yes, I took time to adjust the device because this is a waste of training time. And the second thing is that we have accomplished all that we have accomplished. Welding with the normal machine at a rate of 2 pieces per student except for the only one that did 3, which, as I see, is not enough for the student to reach the	2
		There is a long waiting period, in contrast to the training with the simulator, which allows the students to have more practices and benefit more	9
	2.4 Perceptions of the task: need for more practice-time	*"We need time to stabilize the hand and stop the shaking or trembling. This is the most important thing"*	6
		"I have real difficulty in doing welding in a straight line as I feel that even if I move my hand a little bit, it will go wrong. Managing my hand for this is very hard as my hands shake a lot"	4
		"It was slow. I mean, as I told you, it was possible to feel the lack of previous practice. Need more time and skills, more training, more preparations to get the metal pieces ready for welding, preparation for the machines with wires and gases to	6
		"I feel it at the time of welding the iron plates (pieces) with rust on them, and what I know is that the rust is not good for welding since the weld will not be strong. Of course, before welding the straight line, you must ensure the two pieces are aligned. But if they were rusty, the sparks would go everywhere, and the weld will not be good, I noticed"	8
	2.5 Perceptions of the task and equipment: visibility is an issue in traditional welding with the safety gear	*The vision is also important. How not to wear the same clothes and deal with the machine. This is what I like. It has to be in terms of how hot it is? What is the wire to be used? Any wire? What do I do with the machine itself? This is a skill on its own that requires practice. Also, the challenges. It is how to deal with sparks and electricity, and this is what I could not control because I am afraid of electricity and sparks. It is a big challenge that I overcame yesterday*	5
		And the second thing when I start welding, in the beginning, I was not focused and thought I welded a straight line. When I took off the glasses, I was surprised that my weld was zigzagging right and left and not in a straight line	8
	2.6 Equipment: re-calibration of the actual equipment was challenging	*In terms of calibration, the calibration of the welding machine was also a challenge. The gas ratio meter is a challenge. Additionally, the wire and the appropriate wire feed. I mean, for example, the best thing would be the begin the training with small and lighter wire because the strong wire was a little long, causing holes in the metal during welding. I mean, these are some challenges that we faced generally*	9
		We learnt how to calibrate the welding machine. How to open the gas nozzle. Is the gas type okay? How to identify the correct wire gauge to be used	4

Appendix F: Focused group Cycle 2 Codes and Transcripts (VR and AR (XR) Training)

Codes	Direct Quotes from Participants	Participants
3.1 Perception of the task: XR can help save materials and time	As for the VR, you will gain in saving materials and save time. I knew that we lost the iron right of the instructor, and we lost the gas. These things are learnt without loss when using VR equipment. Okay. You have semi-real training but without loss. We appreciate, as Participant 9 said, that we start with a VR, and it is better to do so based on reducing costs, and the same thing is to gain experience, as he said, at least 40%	4
	We spend more oxygen gas and on consumed materials. I mean, based on what we intend to learn so that one can do this training through the VR firs	10
	We have wasted much material in the traditional training. The VR simulator is better	8
	Also, the skills will be gained with less cost of materials and less time even better than if you are training in real welding and you do 4 to 5 coupons of real welding	5
	The only thing that can resemble reality is virtual training, which can save materials and help you exercise your brain muscles and maintain control of speed, angle and distance while welding, improving muscle memory	1
	The first thing you need to do is some VR training to acquire the skills. I mean, the first thing should be training in virtual reality to gain a skill, which is related to the muscle memory mentioned by Participant 1 and then to train in the real welding machines	2
	In the beginning, just like the PlayStation, you must acquire the skills that require you start welding from speed and then control the distance between the workpiece and welding gun. Then, when you work on the real piece, you can develop the skill day after day	3
	The welding pieces need to be organized and cleaned, which requires a lot of effort and time. And some pieces, although they were cleaned, some pieces will start to rust quickly, unlike preparing a piece for traditional welding, it will be ready and clean in VR	instructor
3.2 Perception of the task: XR technology may help in gaining basic skills before real welding	Of course, it is the best thing to do with virtual reality itself; as we said before, it is better to use virtual reality technology to learn the skill of hand movement. How do you handle the welding pistol? These things, for example, are like these things, then, because when he turns to work on the operator, he will not come down for the workshop and starting to work in the same place, he will have gained experience, at least something that means 40% to 50%, and the work completely acquires the rest	9
	With time and with continuity, the training improves the skills. In the beginning, the first experiment, I was not good at welding, but in the second, third, and fourth time, the skill improved in the welding with the real machines	10
	It was difficult to deal with the real welding machines at first. Because the environment was new, one had to deal a little with it to break this topic to learn about the right distances, learn about right welding speed and control them. The best for the trainer is to learn with VR before he goes to the real welding machine	5
	The VR benefit is teaching angle, distance, speed, but it is not real. Because with the real welding if you will not weld with the correct angle, you will miss up	1
	I see VR at first is better. To learn the welding safety first and then the names of welding components. I see that starting with VR is better. Because you learn how to hold the nozzle right. And you learn the distance between the grip and the handle, which is very important at the beginning	8
	It may be in terms of use, it is possible from the method of welding or the method of the grip, the method of how-to holding welding gun, what do they call the pistol or whatever. For example,how to get the right speed that can be more accurate, the angle, and the angle will be correct so the weld will adhere	6

	3.3 Perception of the task: XR training can remove the fear of heat for the students	I faced issues with learning as the heat distracted me. Welding speed was also an issue for me. If I had used the VR that day, I could have learnt better	8
		There is a benefit; I mean you can break a student's first time fear by allowing them to use the VR first	8
	3.4 Perception of the task A standardised process is necessary for XR	I prefer that each machine or all the welding machines be standardized with the same settings and gas and the same type of wires to make everyone sure of what he is going to deal with. And maybe the instructor did not find the	4
		I think there is more standardisation between the VR and traditional machines that is needed. If the wires and the elements of the machine are the same, the students will find it easy to apply what they have learned from VR to real	instructor1
TH4	4.1 Perception of the task: XR can help with hand stability	If your hands shake, it can help you learn how to stabilize your hand. I mean, it helps me to learn how to weld with the right distance between you and th	8
		"I was able to understand what I was doing wrong and improve my hand stability greatly"	6
		I mean, as the guys mentioned, the VR trains you on the correct hand positioning and the proper way to hold the welding gun	5
	4.2 Perception of the task: XR can be used for fine-tuning skills	I mean, when you have training in the actual workshop, you can learn how to handle the welding gun. All of these details you can learn in the actual workshop. Once you have mastered these skills, you can train via VR simulator	5
		If you have noticed, we were able to learn how to weld in a straight line after being trained in the VR simulator. The simulator helped us in that	4
		Self-improvement. We discussed the advantages of VR training and the problems to avoid. The essential skills gained through VR technology are great, and the trainer is not required to follow up on our mistakes	4
	4.3 Perception of the task: XR can help if the time available for training is short	If time is short, virtual reality training is preferable. If a person can learn from traditional training, he will most likely benefit from VR instruction as well	8
		In the previous year, the number of trainees has grown. 5 trainees can be trained simultaneously. This can never be done in a real workshop. It is really dangerous	7
	4.4 Perception of the task: XR skills translate into real-world skills	I would like to point out that in the VR simulator, you can adjust the voltage automatically. While in the actual welding machine, you cannot do so. One should learn how to do these tasks in reality	2
		More than I had anticipated. As someone who knows very little about welding, I believe I have learned a lot in a short period of time. The VR training accounted for 80% of it, while the practical experience contributed 20%".	4

Th5	5.1 Perception of the task: XR or VR allow to track mistakes and assist in correcting them	The program will do so. VR technology allows us to collect feedback very quickly. Our weaknesses and strengths are displayed on the screen	7
		While you are using the VR training, it instructs you. The red and green lights point to your mistakes and assist you in correcting them	9
	5.2 Perception of the training sequence: Better to start with XR first, followed by traditional	For the VR training, I believe it was sufficient; still, it is better to begin training in the VR and then go to the workshop to put what you have learned into practice	9
		It is a fantastic idea to begin our training with virtual reality. If we had worked in the workshop, I believe we would not have been able to accomplish what we have through VR training. We have learned a lot while using the VR training	7
		One should start with VR training then move on to the practical training. I believe that once I have reached an intermediate level, I should enrol in a practical course	7
		We need 50% VR training and the rest for practical training	2
		30% - 70% or let's say 30–40% for VR – 70-60 % for the traditional course	7
		First, start with the basic with VR, then cover a physics course, after that the practical training	10
		The more I work with the simulator, the more I feel I improve my technique. In addition, I found out that, especially when I work directly after using the Simulator and go to the workshop, my skills are sharp right after	1
	5.3 Perception of the task: XR can help with overcoming the fear of welding	One more thing, at first, the VR training is better; it helps you overcome the fear of using the welding machine	9
		In VR, you know that you are safe I mean no sparks will hit you and no harm will befall you. You are dealing with the VR setup comfortably	6
	5.4 Perception of the task: Gained more skill in XR	I think we have learned the essential skills in the VR. Know how to work with each piece in accordance with the angle and the distance between you and the piece. We learned it all through –the virtual reality simulator. After that, we could apply everything in the actual workshop	10
		It was simple. When virtually welding, there are no flames or smoke. I think it is better with VR Simulation than the actual welding machines in the workshop	9
		The VR simulation is certainly easier. We use a lighter welding gun instead of a heavier one. Also, setting in a room that is air-conditioned is ideal for learning	8
		Yes, learning through VR training was simple. It is the easiest learning method. The anxiety of operating a welding machine is no longer an issue. So, yes, I believe it is simpler	10
		Anyone can easily use the welding gun in the VR simulator. We do not need a trainer to help us. Once we can use the machine, things become easier. You will know how to measure the distance quickly and consider angles	2
		I saw the progress we have made during our practical training. We were able to weld with greater efficiency. Many things have changed for the better. As a result, we can say that the VR training was beneficial to us	5

Th6	6.1 Equipment: A smaller area in XR compared to traditional	The working space available when using the VR machine is small and limited while the space available when using the real welding machine is unlimited	11
		It felt to me that the working area via the VR and AR simulator is constricted and what if I want to train on welding a large work piece?	1
	6.2 Perception of the task: XR cannot accurately re-create the reality of the working environment	The weight of the cable for the actual welding equipment is not the same as the weight for the VR simulator. Also, you should consider the safety measures while working the actual workshop	7
		Also, the helmet is lighter	5
		The heating gun also produces smoke while welding. In a VR simulator, you are not exposed to this smoke	7
		As you have already said, the VR teaches you how to handle the welding machine. But don't you think it costs a lot	5
		You should also consider the suit. You do not need to wear your suit during virtual welding; this can be dangerous in reality. Also, the room in VR simulation is air-conditioned	5
		I can only say that we are not exposed to the hazard of the welding gas. The smell is bad	2
		Compared to the real training. The temperature, the smoke, and several other conditions, such as wearing a helmet, are all factors to consider	7
	6.3 Equipment: XR requires a background in computer	"To be able to work with the simulator, you will need to have some background in computers".	1
		"I believe that extra training would be required for people who are not familiar with using computers unlike the students that are tech savvy".	11
		"VR is easy. But you have to have an idea with using PlayStation so that you can operate it with ease".	5

Appendix G: Focused group Cycle 3 Codes and Transcripts (Hybrid Training XR and traditional)

Codes	Direct Quotes from Participants	Participants
7.1 Perception of the training sequence: Combining XR and traditional training have significant benefits	"I frankly benefited, and the matter affected me very much. Yes, you trained in VR in the first place. I got used to handling the welding gun and immediately went to real welding. I think I had much difference with me".	5
	"It gives me the opportunity or the. Yeah, allow you to work on my angles and. And steadiness and speed. In the. Virtual will already be in. It made it look like it helped me to correct on the move. Well, working. With the. With the equipment in the simulator, the real welding machine is more of well while we are doing that. I can see that. My angles, or I can? I could not adjust my angles. Faster or? In real-time. Then when I was working on the machine, I meant working on the simulator. The more usage I get with the simulator. Help me to adjust. With the real machine.".	1
	"I think the VR training with the traditional training has achieved very good results. I mean, the most thing you can notice. See how we were at the beginning and how we are now. Praise be to God. There is an improvement, but not 100%. Participant 5 said, in VR, we learned how to properly handle the grip, the speed with which your hand moves to weld, and the distance. I mean, if the welding is sparking on you, you are too far. It is necessary to be closer but not too close".	10
	"Yes, overall, you can see that the students are becoming more and more comfortable. I mean more comfortable in the real-world environment. As they improve their skills from the augmented side and bring them over to the real side, you can see that they are more motivated and that there is an improvement. You can tell that the students were more motivated to show their skills. The instructor had a lot less stress in terms of preparation and cleaning coupons and house cleaning, for instance. No waste of material. Furthermore, at the same time, with all of this, the students are enhancing their skill as a welder".	1
7.2 Perception of the training sequence: Combined XR and traditional was beneficial than a single merthod	"It was even better that we came on the second day of working in VR, so that we are better. On the second day, I applied my VR welding learnt skills. Yes, the application is better. The idea is to get used to the routine by holding the handle when you use the VR, hen go practice on the traditional welding machine. For me, I find it better".	5
	"I think the VR training and achievements have yielded outstanding results. I mean, the most you can notice. Look how we were in the beginning, how we are now."	10
	" Of course, the benefit was very great in the workshop. We avoided the mistakes that were present, the fear that existed, for example, through the welding machine or the sparks that existed about it. We came back and learned some mistakes, the method of grip, the method of performance, something new for us, and the practical application was nearby the VR simulators".	6
7.3 Combined training saves time and resources while all participants are engaged.	"Saves time and material and provides faster education".	7
	"It saves time even for the coach teaching the course, I mean, instead of what we took in theory. The VR welding machine shows the instructions".	4
	"We are wasting too much time, and by the time we get on the machine, we are not familiar with it; we tend to be more nervous. The instructor was a bit busy getting us organized to do the training. In addition, before that, the material preparation required time and effort".	1

8.1 Perception of the task: XR helps overcome the fear of welding, but in the same environment	"I support the opinion of the guys. Of course, the benefit was very great in the workshop. We avoided the mistakes and the fear that existed, for example, through the welding machine or the sparks about it. We came back and learned from mistakes, the method of grip, the method of performance, something new for us, and the practical application was close".	6
	"I agree with the guys. I was afraid in the beginning from the electricity sound generated by the real welding machine, but after using the VR machine I feel that this fear is reduced and it keeps reducing with each time I train using the VR equipment".	2
8.2 Perception of the task: Providing more confidence when transitioning from XR to traditional welding	"Because we all experienced the real welding and its dangers, and then we moved to virtual training. as what the guys said, VR enhanced the method of holding the welding gun, the speed, and then we applied the learnt skills again to the real machine in the same way, we benefited many things, and we achieved a very good percentage".	6
	"Of course, what we benefited from the workshop is the period in which we were trained. By default, we worked in a real work environment. I mean, you smell the smell of copper and iron while you hear the sound in the VR. We benefited and realised how we could improve ourselves".	10
	"When you are working on VR, you improve your skill. You adjust the angle, speed, and so on. Then you go to work. Without the gap of time between going	5
	"I enjoy working on the simulator. To me, it is more of a challenge. To get the beads right or to get a good picture when I am finished and look at that. And. Psychologically, I know that I am doing this and not wasting material. However, it stresses me out when I am doing it with the real machine that I have to get it right, or I am wasting time and material. So, I focus more on getting my beads right or my speed right when I do it with the real machine. Because I do not want it to go to waste".	1
9.1 Perception of the task: Need to try and emulate or replicate the real welding experience	"It was an OK experience; of course, the VR at the beginning is better. For example, we set the VR in the place of the welding workshop. For example, the same student comes, the first one who achieves 90% in the VR score goes to real welding".	8
	"In short, instead of the VR being located in an air-conditioned place isolated from the workshop, you live the practical atmosphere in general from the sound of real welding to the sparks that came out when the VR machines are placed in the workshop, I mean, even when the instructor told us about the need to wear welding clothes, and I wore welding clothes and tried to weld with the VR simulator while wearing the real PPE, so it felt more like a real environment but in VR, and frankly, it makes a difference."	5
	"We should utilize all the equipment available to make it more real. Instructors should enforce gloves and protective gear so the student can feel like he is in a real environment. The augmented reality needs some improvement in making it more real or feel more real in other dimensional situations where they might want to increase vibration with the torch or Sound vibration. Maybe heat simulators or something like that. Sound, vibration and other dimensions help create a real environment".	1
	"The actual feeling you get with the torch is where the difference is. However, at the same time, it really helps you with the angles because augmented reality does not allow you to go off, cheat, or miss that angle without it showing up on the screen. So, it helps you to take that technique over to the shell".	1

Appendix H: Experience of the Instructors Codes and Transcripts

Codes	Transcripts	Instructors
10.1 Equipment: **No difficulty in training with combined XR and traditional**	"There was no difficulty training with the combination of the VR and AR and the traditional welding machines. I was comfortable training with a virtual reality simulator because it works as an observer on the other side with the students, meaning an observer and an assistant. And as an instructor, I was comfortable with it as it allowed me to focus with the students working with the real welding machines"	1
	"I much prefer VR training (XR training) than traditional machine methods, where you train comfortably without fear of fire. While working in welding workshop requires more precautions and attention to safety.The VR has helped me teach the welding quickly"	5
10.2 Training experience: **More control over the students**	"No difficulties because I could train and control the students more effectively.... In the third-cycle training, the risks of working in the workshop have been reduced to a minimum.	1
	And also, one by one, they have to learn, uh, according to parameters, but these students, but with the VR, it was very easy to control"	2
	Additionally, the machines that's, and that's another benefit to where the using the AR machines, the machines would help the students on the spot right away. So, while they were, they are working, uh, and welding, um, a piece for example, or a coupon, the machine would give them directions as they go	3
10.3 Training experience: **Seamless training experience using XR**	"it shortened much work on monitoring students and preparing for practical training for everyone. Not to mention that the third cycle training allows us to avoid the interruption to training such as running out of gas, and if it happened, I could easily switch to the virtual training simulator"	1
	"Students in the VR, they are feeling the very good environment, same environment, especially they're getting confidence with the VR.Okay. This confidence leads them in, in future becomes a very good welder"	2
	"What I have noticed is, uh, it was very good experience with my students and as well as in my class, uh, every it, as we have immersed with the VR, uh, students were more engaged and they were learning better"	3
	"I prefer to start using VR in welding teaching, where the student can learn more and gradually by applying the required right distances as shown on the screen, adjusting angles and correcting errors.	4
	"The use of VR is economical and reduces costs because gas cylinders, welding wires, gloves, helmets, welding glassesand vests and PPE are not used in it. The student also feels safe from the possibility of fire or gas leakage and etc. Students also find themselves in an atmosphere of competitive and motivational spirit to learn something new"	5
10.4 Equipment: **Safety control is more efficient with XR**	"Also, with the new third cycle training, the dangerous factors in the workshop were minimized. Students controlled dealing with flying sparks and flames or cutting iron,	1
	VR is also good for the safety measures because safety in the traditional welding is different. Like students, sometimes they are scared about starting the welding. And if they see some, um, sparks, they have some time this, these sparks gone to their shoes, sometime their glove sometime on their body	2

10.5 Training experience: **Better communication of errors in XR compared to traditional welding**	VR training, communication was smother. I mean, while using the traditional machine, the student does not hear you when you talk to him, or if you want to guide him for something.....In terms of communication with the students, it was hard with the traditional welding machines students."	1
	communication with the VR was very easy and students focus	2
	"...in terms of communication, the overall general, uh, thing that we noticed is that it was communication was much easier with the students than if, when using traditional only"	3
	the communication with them were very, very easy.	4
10.6 Training experience and equipment: **Combined was better than single of delivery**	"In the third cycle, we avoided the waiting time and waste materials for the first cycle and the cons of the virtual Reality only training cycle. With the third cycle, we effectively achieved our training objectives, engaged all the students, and eliminated the waiting time where the students had nothing to do until the machines were free".	1
10.7 Training experience: **Starting with XR is a good option**	"Starting with the VR in the workshop allows the students to master the skills required, such as the right angle, speed and distance. After that, he can go to welding using the traditional machine. Nevertheless, the students improved their skills this time, and I noticed that most of them did very well.....But by virtual Reality, you get every student to at least weld five or six pieces, meaning three times and four times as much as traditional	1
	"For the beginning, VR one is the essential, but in traditional some students, they are not good for beginning, especially when they have the problems when they are, they are they don't have any, uh, mathematics, like, especiallydiameter of the electrodes like this"	2
10.8 Training experience: **Real-time rectification of mistakes and errors**	"Whenever a particular mistake is made by the student in the traditional welding machine, the trainer immediately sends the student to the virtual reality simulator to practice and correct the mistake and then return to the real welding".	1
	"Therefore, I was able to concentrate more on them and the students using VR, where basically on auto mode or autopilot mode, they were doing it all on their own. The machine was giving them the feedback. So, I only needed to give them, uh, some tips in the beginning"	2
Equipment: **The need to emulate or replicate the real welding experie**	"The increase in realism in training, because in addition to protective clothing, there is the general atmosphere of working in the workshop, which from my point of view and my experience in training contributed a lot to making the student not feel that the virtual reality device is just a computer or a game because during the training in the workshop the student heard the sound of real welding machines ....and he feels the heat, gases and smells from the welding machines, in addition to that student is feeling that he is working such as real welding"	2
	"What I noticed is that when they used the VR machine in the workshop, that fear was almost gone, it, it did not exist with them as much because they got used to it from, uh, the VR machine, which is a much safer way of obtaining this experience".	3
	"We have to put both simulator and the traditional, uh, equipment in the same workshop. So, the both, if they are closer to the, like, if they are in the same workshop, that would be the best".	4
	"The use of VR in welding is also insufficient on its own in training for a range of reasons. First, the VR does not reflect the realism of the welding process and its real atmosphere of sparks, heat and real welding components. The student must go to the real welding workshop (booth) for real welding training and recognize real errors that do not appear on the VR such as holes or real welding stuck stick. Traditional welding and VR are therefore indispensable together to complement each other"	5
	"The VR also lacks the realism which found inside the real welding workshop, since the results appear only visible and intangible on the displayed screen. VR also lacks the principle of calibration in which students cannot calibrate the equipment to start work"	6
10.10 Training experience and equipment: **Instructors can evaluate the performance of students post-training**	"One of the advantages of the virtual reality simulator enables the teacher to follow up on each student and how much time he has spent training and what his mistakes are through the database feature for trainees in preparing the virtual reality"	1
	"At the same time, I benefited from the VR using the data recorded in it for students' attempts. It helped me greatly in making a file for each student and monitoring his results and reports on the evolution of his skills	5
10.11 Equipment: **XR (AR/VR) technology welding training devices offers mobility of the training services**	"In the third action cycle and before the combined training methods I managed smoothly to move the A/VR welding simulators from the VR lab to the welding workshop, also when i set up the AR/VR welding simulator again it was very easy and saved the instructor time"	1
	"I didn't find moving the AR and VR simulators difficult and with the package it was easy to pack and move it anywhere, this will help training welders in remote places"	4
	"Moving the VR simulator was very easy and it was like moving a desktop computer from one office to other and the good thing is the special package helped the instructor to pack the VR and move it anywhere without any issues"	5
	"The Virtual reality welding simulator weight was not heavy and we moved to the allied trades workshop very easily and when we just plugged the simulator to the electricity cable and we managed to train the students again".	3