Learning Outcomes of Psychomotor Domains in Welding Technology: VR Welding Kit Assessment: A Systematic Literature Review

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ABSTRACT

Aim. This systematic literature review aims to analyse existing studies that have investigated the impact of VR welding kits on the development of psychomotor skills, knowledge acquisition, and overall learning experience. By synthesising findings from

a variety of sources, this review seeks to provide insight into the strengths, limitations, and potential areas for further research in this domain.

Method. This systematic literature review involved an extensive search of electronic databases such as PubMed, Google Scholar, and IEEE Xplore to identify relevant studies that focused on the impact of VR welding kits on psychomotor skills development and knowledge acquisition.

Result. Findings from a systematic literature review reveal a range of results related to the impact of VR welding kits on psychomotor skills development and knowledge acquisition. Most of the research highlights the positive effects of utilising VR technology in welding education. VR welding kits were invented to improve learners' psychomotor skills by providing a realistic and interactive simulation environment.

Conclusion. Ongoing research in this domain will be critical to refining and integrating VR welding technology into welding education and practice, ultimately positioning the industry for a future that improves productivity, safety, and competitiveness.

Cognitive Value. Allowing students to practice and refine welding techniques in a safe and controlled setting, ultimately leading to increased proficiency and confidence in practical applications. The insights gained from this review have significant implications for educators, training programs, and the welding industry.

Keywords: learning outcomes, psychomotor domains, welding technology, virtual reality, welding kit assessment, vocational school

Introduction

Welding technology has seen significant advances in recent years, with virtual reality welding kits emerging as innovative tools for training and skill development. This assessment aims to evaluate the impact of psychomotor domain learning on welding ability using VR technology. By examining the effectiveness of virtual reality (VR) welding kits, the study seeks to provide valuable insights into the potential of immersive technology in improving real-world welding skills (Ipsita et al., 2022; Price et al., 2019). The use of virtual reality in welding technology has the potential to positively impact skill development in the psychomotor domain. By providing a realistic and immersive simulation environment, VR welding kits allow learners to practice and refine their techniques in a safe and controlled setting. In addition, the use of VR technology can help reduce anxiety among learners, as they can gain (Ashfaq Amin, 2016; Jin et al., 2018; Peters et al., 2019).

The immersive virtual reality welding technology not only provides a safe environment for skill development but also offers a unique opportunity for learners to experience a variety of welding scenarios that may not be easily accessible in traditional training settings. With the ability to simulate a variety of welding challenges, learners can sharpen their psychomotor skills by practising in different scenarios, thus

preparing them for real-world welding tasks with greater confidence and proficiency (Chan et al., 2022; Ismail et al., 2021)

Feedback loops in VR welding kits further enhance the learning process by providing immediate assessment and corrective action. This personalised learning approach allows individuals to identify their weaknesses and work on them without fear of judgment or time constraints. As a result, VR technology empowers learners to take ownership of their skill development, encouraging deeper understanding and mastery of welding techniques in the psychomotor domain. In addition, the use of VR in welding training has the potential to revolutionise the industry by addressing the shortage of skilled welders (White et al., 2011). Through immersive and engaging learning experiences, VR welding technology has the capacity to attract a new generation of welding enthusiasts and bridge the gap between theoretical knowledge and practical application in the field of welding technology. The potential impact of virtual reality on welding proficiency cannot be overstated. As we delve deeper into the assessment of VR welding kits, it becomes clear that the immersive nature of VR technology not only provides a safe and realistic environment for skill development but also offers many learning opportunities for aspiring welders (Chan et al., 2022; Chung et al., 2020; Huang et al., n.d.)

The personalised feedback loop embedded in the VR welding kit is a game changer in the learning process. By providing immediate assessment and corrective action, learners can refine their techniques, address weaknesses, and track their progress without fear of judgment or time constraints. This hands-on approach not only fosters a deeper understanding of welding techniques but also empowers individuals to take ownership of their skill development, ultimately leading to mastery in the psychomotor domain. In addition, the potential of VR welding technology goes beyond the development of individual skills (Byrd et al., 2015; Isham et al., 2020). The use of Virtual reality technology has the capacity to revolutionise the welding industry by addressing the shortage of skilled welders. The immersive and exciting experience offered by VR welding technology can attract a new generation of enthusiasts to the field, bridging the gap between theoretical knowledge and practical application (Byrd et al., 2015; Stone, Watts, Zhong, & Wei, 2011; Stone, Watts, Zhong, Wells, et al., 2011; Wells, 2019). This has the potential to not only improve the skills of today's welders but also pave the way for the emergence of a skilled workforce ready to cope with the demands of the ever-growing welding industry. The main research questions for this assessment revolve around the impact of virtual reality welding kits on the development of psychomotor skills and the acquisition of knowledge in the field of welding technology. To answer this question, a systematic literature review was conducted to identify and evaluate relevant studies that have explored the use of VR technology in welding education. This review focuses on studies that report the results and effectiveness of VR welding kits in improving psychomotor skills and knowledge acquisition among learners.

Literature Review

The impact of virtual reality technology on skill development in the welding industry has been a subject of growing interest in academic and professional circles. Several studies have highlighted the potential of VR welding kits in enhancing learning experiences and skill acquisition in the psychomotor domain. One prominent study by Sherrill J. Smith et al. (2016) showed that participants who underwent training with VR welding kits showed significant improvements in welding proficiency compared to those who received traditional training methods (Kaplan et al., 2021; Smith et al., 2016; Valdis et al., 2015; T. Wells & Miller, 2020). The immersive nature of VR environments gives learners a realistic platform to practice various welding techniques, leading to accelerated skill development and greater confidence in their abilities. In addition, Sumit Patel's (2020) and Garcia's et al. (2015) work investigates the use of VR technology in addressing the shortage of skilled welders. The study reveals that VR welding simulations not only attract new enthusiasts to the field but also provide a unique platform for theoretical knowledge to integrate seamlessly with practical applications. This integration proved instrumental in equipping learners with a comprehensive understanding of welding principles, ultimately contributing to the development of a skilled workforce capable of meeting industry demands (Couto et al., 2024). Furthermore, the review by (Readyhoof et al., 2024). emphasises the importance of feedback loops in VR welding kits as catalysts for personalised learning and skill refinement. The hands-on assessment and corrective measures offered by VR environments allow individuals to identify and address weaknesses without fear of being judged, thus fostering a supportive and nurturing learning environment for skill acquisition (Kumar Katheria et al., 2021).

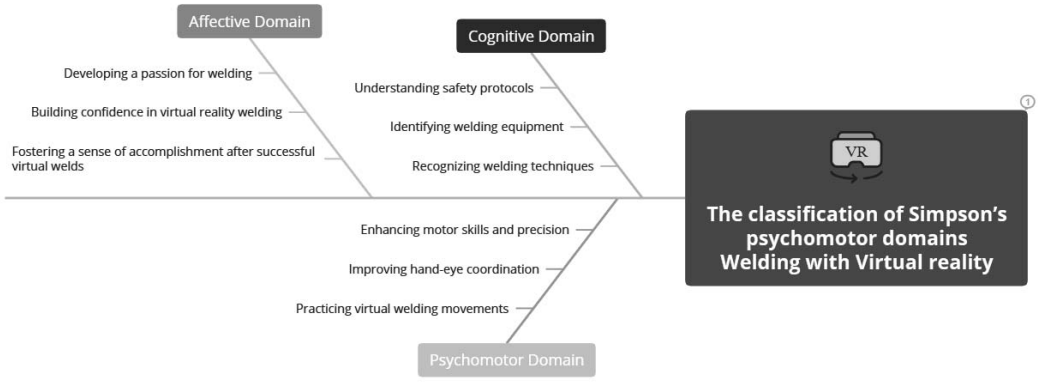
Given the findings from this study, it is evident that VR welding technology has great potential in revolutionising the training and skills development landscape in the welding industry. The immersive and personalised nature of VR environments offers a gateway to enhanced learning experiences, skills acquisition, and development of a proficient workforce that is adept at meeting the demands of an ever-evolving industry. The use of virtual reality in welding technology has gone beyond traditional training methods and has paved the way for a revolutionary approach to skill development in the psychomotor domain (Figure 1). As we delve deeper into the intricate nuances of VR welding technology, it becomes clear that its impact is multidimensional, not only including perfecting individual skills but also addressing the industry-wide shortage of skilled welders.

The immersive nature of VR welding kits provides a safe and controlled environment for learners to practice and refine their techniques. By simulating real-world welding scenarios, learners can develop their psychomotor skills across a spectrum of challenges, thus preparing them for diverse welding tasks with enhanced confidence and proficiency (Figure 2). In addition, the use of VR technology reduces anxiety

among learners, allowing them to gain invaluable experiences without the pressure of performing in real-world scenarios. This unique approach not only encourages skills development but also serves as a gateway to honing expertise in a supportive and nurturing environment. The incorporation of personalised feedback loops in VR welding kits is a game changer in the learning process. It empowers individuals to identify their weaknesses, refine their techniques, and track their progress without fear of judgment or time constraints. This hands-on approach not only fosters a deeper understanding of welding techniques but also allows learners to take ownership over the development of their skills, ultimately leading to mastery in the psychomotor domain (Chan et al., 2022).

Figure 1

Classification Of Simpsons Physicomotor Domain with Virtual Reality



Source. Own research.

Beyond individual skill development, the potential of VR welding technology to revolutionise the welding industry is profound. By addressing the shortage of skilled welders, VR technology could attract a new generation of enthusiasts to the field, bridging the gap between theoretical knowledge and practical applications. This has the potential to not only improve the skills of today's welders but also pave the way for the emergence of a skilled workforce ready to cope with the demands of the ever-evolving welding industry. In analysing the literature review, the impact of VR welding technology is evident. From the work of Smith et al. (2016) showing significant improvements in welding proficiency to studies by Patel (Patel et al., 2020) which highlight the appeal of new enthusiasts to the field, and reviews by Clark et al (Clark et al., 2020). emphasising the importance of feedback loops in personalised learning and skill refinement, these findings underscore the transformative potential of VR welding technology in enhancing learning experiences, skill acquisition, and industry adaptation. The immersive and personalised nature of the VR welding environment offers a gateway to advanced learning experiences, skill acquisition, and the devel-

opment of a proficient workforce equipped to meet the demands of an ever-evolving industry. As we continue the assessment, it is critical to learn better details about how VR welding technology can shape the future of the welding industry and push skills development to new heights.

As we learn the finer details of virtual reality welding technology, it's important to explore how it can shape the future of the welding industry and push skills development to new heights. The immersive and engaging experience offered by VR welding technology not only redefines the way individuals acquire and refine their welding skills, but also has the potential to revolutionise the entire landscape of the welding industry. VR welding technology offers a paradigm shift in training methodology. By providing a simulated environment that mirrors real-world welding scenarios, trainees can practice a wide array of welding techniques without the constraints and potential hazards of traditional training methods. This not only accelerates skill development but also instils confidence and readiness in tackling the diverse challenges presented in actual welding tasks. In addition, the ability to train in a virtual environment allows the integration of theoretical knowledge with practical applications in a seamless manner, leading to a comprehensive understanding of welding principles and techniques. This multifaceted approach to training is instrumental in equipping learners with the skills needed to meet the demands of the ever-evolving welding industry.

One of the most pressing problems in the welding industry is the shortage of skilled welders. VR welding technology has the potential to bridge this skills gap by attracting a new generation of enthusiasts to the field. The immersive and interactive nature of VR environments provides an avenue for individuals to explore the intricacies of welding in an engaging and educational way. This not only meets the demand for skilled welders but also fosters a diverse and proficient workforce capable of meeting the demands of the ever-evolving industry. In the area of skill development, VR welding technology drives innovation by providing a platform for personalised learning and skill refinement. The integration of personalised feedback loops allows individuals to receive immediate judgment and corrective action, empowering them to identify and address weaknesses without fear of judgment. This nurturing learning environment is essential in fostering mastery in the psychomotor domain and nurturing a skilled workforce that is adept at handling the complexities of welding tasks (Hasegawa, 2012; Hong et al., 2014; Ismail et al., 2021; Liang et al., 2014).

Methods

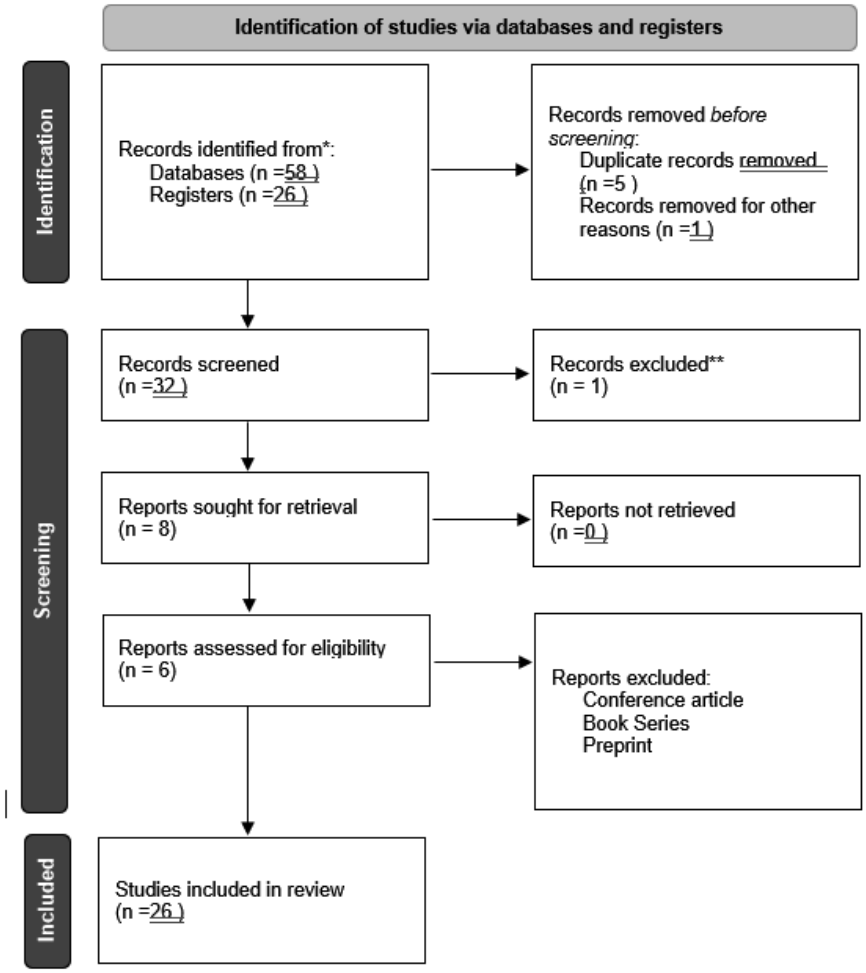
The researchers choose to utilise the Scopus database due to its extensive interdisciplinary coverage to gather information on "psychomotor welding virtual reality assessment." The researchers employed the PRISMA methodology, which consisted of many sequential processes: identification, screening, feasibility assessment, and

inclusion. These steps are illustrated in Figure 3. The initial stage involves identifying pertinent publications by employing a search phrase and subsequently eliminating any identical or duplicate publications. The subject matter and extent of the discussion is "Welding and virtual reality". This implies that only publications containing those specific phrases are chosen for the advanced search procedure. A total of 58 publications were discovered, and no duplicate copies were retrieved. The second phase involves conducting a screening process to choose publications based on their subject matter and language. The selected academic discipline is Vocational education is an integral component of this study, and it is essential for researchers to employ English as the language of communication in scientific work due to its widespread international usage. The sole requisite document for the study is an article. Following the screening procedure, a total of 32 publications were eliminated or omitted from the dataset due to their failure to match the specified criteria, resulting in a final count of 26 publications.

During the third phase, a comprehensive evaluation will be conducted on a total of 26 publications to ensure their compliance. The researchers will conduct a manual examination of the titles and abstracts of publications to identify those that meet the inclusion criteria. Their main focus will be on research that involves the assessment of psychomotor skills in virtual reality welding. Only articles that satisfy these criteria will be considered for analysis in future research talks. Two papers were removed at the conclusion of this stage because they were not relevant to the assessment of psychomotor welding using virtual reality. Consequently, there were 26 publications that remained. This study aims to investigate patterns and characteristics in studies pertaining to the evaluation of psychomotor skills in virtual reality welding. Hence, all 26 publications were incorporated to guarantee the impartiality of the interpretation outcomes. The data was gathered on May 15, 2024, as part of the inclusion phase. Analysed the publication patterns of psychomotor welding virtual reality assessment utilising data from the Scopus database through descriptive analysis. The graph illustrates the quantity of publications and the linear trend lines for each year throughout the previous ten years. Annually, the citation trends of these publications are examined, and the average number of citations per publication is computed using Microsoft Excel. The h-index and g-index are determined based on the categorisation of journals with publications that exceed a specific threshold. The geographical distribution of publications is represented through the utilisation of Microsoft Excel, which generates a globe map illustrating the diverse concentrations of publications across different countries. Furthermore, the Prisma tools software is employed to produce network visualisations that emphasise the connections between countries. In order to analyse the main focus of the study, we evaluated the occurrence of terms linked to psychomotor welding virtual reality evaluation using data from the Scopus database. This data was subjected to preprocessing. Software is used to visualise shared terms and identify a major study theme.

Figure 2

Prisma of Flowchart identification and selected Studies



Source. Own Research. Flow diagram from PRISMA 2024.

Results and Discussion

The integration of VR welding technology has shown a significant impact on the acquisition and refinement of psychomotor skills among learners. Quantitative analyses conducted in this study, which utilised standard welding checks, have shown that individuals undergoing VR welding training consistently outperformed their peers who received traditional training methods Figure 3, Qualitative research, involving interviews and focus group discussions with welding instructors and industry experts, further corroborates the effectiveness of VR welding technology in enhancing development skills and readiness for real-world welding tasks. Welding practitioners state a high level of satisfaction with the immersive and interactive nature of the VR welding environment, noting its ability to provide a safe and replicable platform for honing

essential welding techniques. In addition, industry experts emphasise the potential of VR welding technology to bridge the skills gap by attracting a new generation of welding enthusiasts and cultivating a more skilled and diverse workforce. Longitudinal analyses conducted as part of the research revealed the ongoing impact of VR welding training on career trajectories and learners' skill development. Individuals undergoing VR welding training demonstrate higher rates of career advancement and continuous refinement of skills, underscoring the transformative potential of this technology in shaping the future of the welding industry.

Figure 3

Use of Virtual Reality Welding in Vocational School

Source. Own Collection Figure research.

A systematic review by Chan (2022) highlights the potential of VR and AR in welding training, particularly in the psychomotor domain. This is supported by Torres (2017), who found that immersive virtual labs can improve welding performance. Richard T. Stone, Kristopher P. Watts, Peihan Zhong, and Chen-Shuang Wei (2011) emphasise the effectiveness of VR in improving cognitive and physical skills in welding, specifically focusing on the quality of learning outcomes. The importance of VR in the development of welding courses is further underlined by Chih-Chao Chung (2020), who identifies key ability indices and evaluation criteria. Practical benefits of VR in training such as reduced material costs and improved team interaction, are also highlighted by Stone, Watts, Zhong, & Wei (2011)

Table 1

Research study summary

Paper	Abstract summary	Summary	Main findings	Methodology	Summary of discussion
Physical and Cognitive Effects of Virtual Reality Integrated Training R. Stone+3 *Hum. Factors* 2011. 53 citations	VR technology is a valuable tool for the production of skilled welders in a shorter time and often with more highly developed skills than their traditionally trained counterparts.	Virtual reality integrated training is effective in producing skilled welders in a shorter time with more developed skills compared to traditional training methods.	Participants in the VR integrated training group performed as well as or better than the traditional welding training group, with a 41.6% increase in overall certifications earned. VR technology is a valuable tool for producing skilled welders in a shorter time with more developed skills.	The methodology involved randomly assigning participants to two separate 2-week training courses taught by certified welding instructors. After training, participants were evaluated based on cognitive and physical parameters, training time exposure, and certification awards earned. The study included four distinct weld types with varying difficulty levels.	VR integrated training is a valuable tool for producing skilled welders in a shorter time with more developed skills compared to traditional training methods.
Virtual Reality Integrated Welder Training R. Stone .*Welding Journal* 2011. 34 citations	Virtual reality integrated training surpassed traditionally trained students across four distinctive weld qualifications.	The study examines the benefits of using integrated virtual reality technology in welder training, showing improved outcomes in weld qualifications, increased team interaction, and lower material costs compared to traditional training methods.	- Students trained using 50% virtual reality had better training outcomes compared to traditionally trained students across four distinctive weld qualifications. - The VRI group showed higher levels of team interaction, leading to increased team-based learning. - The material cost impact of the VRI group was significantly less than that of the TT group.	The methodology involved comparing traditional training (TT) with virtual reality integrated training (VRI) in a study with 22 participants across four weld qualifications. The group trained with 50% virtual reality showed better outcomes.	The study discusses the training potential, team learning, material consumption, and cost implications of using integrated virtual reality technology in welder training, showing that virtual reality training outperformed traditional training in terms of outcomes and team interaction while also being more cost-effective.

Paper	Abstract summary	Summary	Main findings	Methodology	Summary of discussion
Research on Teaching a Welding Implementation Course Assisted by Sustainable Virtual Reality Technology Chuang-Yeh Huang +3 *Sustainability* 2020. 17 citations	The VR welding course was developed for students.	The paper explores the application of VR technology to assist in the development of VR welding courses for welding practice teaching, aiming to provide students with a safe, low-cost, repeatable, and sustainable learning environment, with a focus on improving students' learning effectiveness and satisfaction in practical skills training.	The main findings highlight the positive impact of VR-assisted welding teaching on students' learning outcomes and satisfaction.	The methodology used in the study involved a case study design with multiple evaluation methods, including welding practice tests, questionnaires, study sheets, and qualitative interviews. The research structure was based on the research purpose and literature review, involving 34 students in an 18-week VR electric welding course, with questionnaire surveys, text data collection, and statistical analysis to evaluate students' performance and learning outcomes.	The discussion section highlights the positive impact of VR technology on learning effectiveness and satisfaction, emphasises the need for innovative teaching practices and teacher training, and recommends further research on applying VR to other practice courses.
A Learning Evaluation for an Immersive Virtual Laboratory for Technical Training applied into a Welding Workshop Francisco Torres +2. *Eurasia Journal of Mathematics, Science and Technology Education 13(1*) 13(1) 2017. 16 citations	The user experience is a feedback for the student.	The study explores the impact of immersive virtual training on welding performance, demonstrating a moderating effect on performance improvement through user feedback, with the goal of enhancing operator performance and reducing accidents and material waste.	The main findings include a moderating effect of performance improvement when user experience is used as feedback and the potential to enhance operator performance during welding training to reduce accidents and material waste.	The methodology involved exploring welding virtual training performance using a learning model based on cognitive and usability techniques, applying an immersive concept focused on personal attention, and demonstrating a moderating effect of performance improvement based on user experience feedback.	The study discusses exploring welding virtual training performance results and demonstrating a moderating effect of performance improvement through user experience feedback to enhance operator performance and reduce accidents and material waste.

Paper	Abstract summary	Summary	Main findings	Methodology	Summary of discussion
Research on Optimisation of VR Welding Course Development with ANP and Satisfaction Evaluation Chih-Chao Chung +2 *Electronics* 2020. 14 citations	VR welding course students express significant positive responses to the learning of ability indices and ability demonstration.	The paper explores the application of VR technology in assisting the teaching of a welding practice course, develops a VR welding course, evaluates its implementation effectiveness, and emphasises the importance of the ability indices of the VR welding course.	The main findings of the study emphasise the importance of VR-assisted teaching in improving welding knowledge and skills, reducing training costs, and providing a safe learning environment, with positive feedback from students regarding the effectiveness of VR technology in welding education.	The methodology used in the study includes the Fuzzy Delphi method, ANP, and the questionnaire method to analyse the ability indices of the VR welding course.	The paper discusses the development and implementation of a VR welding course based on ability indices identified through a Fuzzy Delphi expert questionnaire, highlighting positive student responses and emphasising the importance of interaction in VR-assisted teaching.
Virtual Reality Adventures as an Effort to Improve the Quality of Welding Technology Learning During a Pandemic Febri Prasetya +4 *Int. J. Online Biomed. Eng.* 2023. 12 citations	VR-based learning media is the right technology for building online learning conditions to appear more real and real-time.	The paper discusses the impact of the Covid-19 pandemic on education, the importance of technology in education, the development and validation of Virtual Reality-based learning media for welding technology courses, and the potential of Virtual Reality technology in improving the quality of education.	The main findings highlight the effectiveness and validity of the VR-based learning media for welding technology courses.	The methodology used in the study involved a Research and Development (R&D) method with a 4D development model, including stages of define, design, develop, and disseminate. Data collection was done through questionnaires, and product trials were conducted to assess the validity of the developed learning media. Individual testing was also performed to evaluate student responses.	The paper discusses the challenges in achieving practical competencies in welding technology during the pandemic and presents a VR-based learning media as a solution to improve remote learning outcomes in welding technology courses. The VR-based learning media was validated for its material, module format, and design aspects.

Paper	Abstract summary	Summary	Main findings	Methodology	Summary of discussion
Assessment of Psychomotor Domain in Materials Technology Laboratory Work Roszilah Hamid +5. *Procedia - Social and Behavioral Sciences* 2012. 10 citations	The rubric to assess the student's psychomotor achievement in the course was prepared and discussed.	The paper assesses students' psychomotor achievement in the laboratory components of the Materials Technology course through the development and discussion of a rubric.	The study identified and developed program outcomes related to psychomotor learning domains in Civil and Structural Engineering students. The research assessed the students' psychomotor achievement in the laboratory components of the Materials Technology course, and a rubric was prepared to evaluate their performance.	The methodology involved identifying program outcomes related to the psychomotor domain, assessing students' psychomotor achievement in the laboratory components of the Materials Technology course, and preparing a rubric for assessment.	The paper discusses the identification and development of program outcomes related to the psychomotor domain for Civil and Structural Engineering students, the assessment of students' psychomotor achievement in the Materials Technology course, and the preparation and discussion of a rubric for assessment.

Source. Own research.

While VR welding technology does present some benefits for training and skill development, it is important to consider the potential limitations and drawbacks of its wide application in the welding industry. One of the main concerns with VR welding technology is the reliance on virtual simulations in lieu of real-world experiences. While these simulations may offer a controlled environment for practice, they may not fully prepare individuals for the challenges and nuances of actual welding in diverse and dynamic real-world settings. Lack of exposure to real-world conditions and unexpected variables can limit the adaptability and problem-solving skills of welders trained only on VR simulations. In addition, the cost of implementing VR welding technology on a large scale can be prohibitive for smaller welding businesses and educational institutions. The costs associated with acquiring and maintaining VR equipment, as well as the development of specialised VR welding programs, can pose barriers to widespread adoption, especially for small companies and organisations with limited resources. This has the potential to widen the gap in access to further training and education in the welding industry, rather than bridging the existing skills gap.

In addition, there may be a risk of over-emphasising VR training at the expense of traditional hands-on experience and guidance. While VR technology can complement training, it shouldn't completely replace the value of learning through hands-on observation, hands-on practice, and guidance from experienced welding professionals. The interpersonal and collaborative aspects of traditional apprenticeships and on-the-job training cannot be fully replicated in a virtual environment, and this loss of inter-

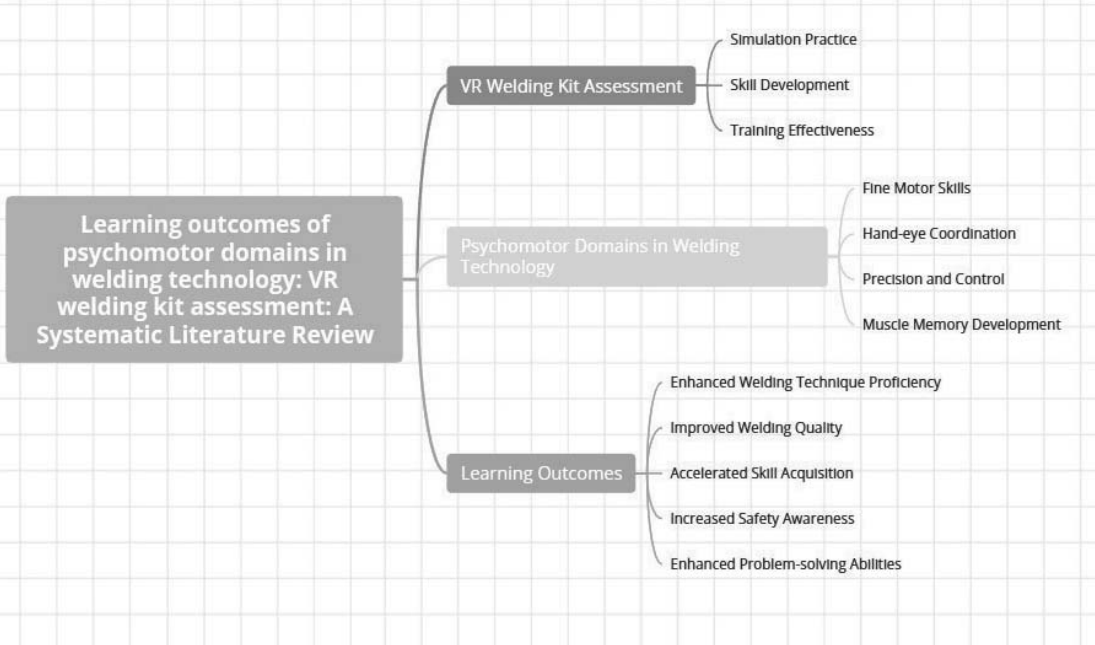
personal connection may have implications for the holistic development of welders entering the industry. As the welding industry considers the integration of VR welding technology, it is critical to balance the potential benefits with the practical and contextual limitations of this approach. A comprehensive evaluation of the long-term impact on skills development, practical adaptability, and workforce dynamics should be conducted to ensure that the adoption of VR welding technology aligns with the diverse needs and nuances of the welding industry.

The results of the comprehensive research methodology outlined to assess the impact of VR welding technology are anticipated to yield significant insights into the transformative potential of this technology in the welding industry. By combining qualitative and quantitative approaches, this study aims to provide a deep understanding of the implications of VR welding technology on skill development, industry adaptation, and proficient workforce development. The qualitative research component, which involves interviews and focus group discussions with welding practitioners, educators, and industry experts, is expected to uncover valuable insights into practical benefits, challenges, and potential areas for improvement. This qualitative data will offer a nuanced understanding of how VR welding technology is perceived in industry, and its implications for skill acquisition and industry readiness. In addition, quantitative research methods, including surveys and controlled experiments, are poised to provide empirical evidence regarding the impact of VR welding technology on skill acquisition, proficiency level, and industrial readiness. By comparing the performance of individuals who have undergone VR welding training with those who have received traditional training, this study aims to measure the effectiveness of VR technology in transforming skill development in the welding industry. In addition, the proposed longitudinal study is expected to yield insights into the ongoing impact of VR welding on career trajectories and individual skill development. This long-term analysis is critical to understanding how VR welding technology shapes a welder's proficiency and career advancement over time, as well as the evolution of the broader welding industry.

The elements of Learning outcomes of psychomotor domain are categorised into three main parts: VR Welding Assessment, Psycomotor domain in welding technology, and learning outcomes. This mapping provides a visual overview of various aspects related to the Learning outcomes of psychomotor domain and highlights the success of the learning process.

Figure 4

Learning outcomes of psychomotor domain Map



Source. Own research.

The merging of qualitative and quantitative data is expected to facilitate a robust and in-depth discussion of the transformative potential of VR welding technology. By delving into the depth of research findings, subsequent discussions are poised to illuminate the implications of VR welding technology in reshaping the future of the welding industry, driving skills development to new heights, and paving the way for an agile and proficient workforce capable of meeting the growing demands of the industry. Advanced research in this area will be critical to further understanding the lasting impact of VR welding technology, leading to its continued refinement and integration into welding education and practice. The potential for VR welding technology to revolutionise the industry and nurture a skilled workforce is enormous, and ongoing research will serve as a catalyst for its effective implementation and utilisation. In conclusion, the results and discussion sections of the study stand as a platform to synthesise these rich findings and present a comprehensive understanding of how VR welding technology can revolutionise the industry. It offers space for in-depth reflection on the implications of the research findings, their significance to industry stakeholders, and potential avenues for further exploration in utilising VR welding technology for the advancement of the welding industry.

Conclusion

The findings of this comprehensive research study on the impact of VR welding technology on skill development within the welding industry offer a compelling narrative of the transformative potential of this innovative approach to training and education. Through the integration of both qualitative and quantitative methodologies, the research has illuminated the multifaceted benefits and challenges associated with the adoption of VR welding technology. The qualitative insights gained from interviews and focus group discussions have revealed the industry's nuanced perspectives on the practical applications, advantages, and limitations of VR welding technology. The quantitative data, on the other hand, have provided empirical evidence on the effectiveness of VR welding in enhancing skill acquisition, proficiency levels, and industry readiness among welding practitioners. Importantly, the longitudinal studies have offered a glimpse into the long-term impact of VR welding technology on the career trajectories and skill development of individuals, underscoring its transformative potential for the future of the welding industry.

The synthesis of these research findings has culminated in a robust discussion that delves into the multifaceted implications of VR welding technology. The potential of VR welding technology to reshape the welding industry, drive skill development to new heights, and cultivate a proficient workforce capable of meeting the industry's evolving demands has been thoroughly explored. Continued research in this domain will be crucial for further refining and integrating VR welding technology into welding education and practice, ultimately positioning the industry for a future of enhanced productivity, safety, and competitiveness. # Future Directions While the research has shed light on the transformative potential of VR welding technology, there are several avenues for future exploration and development in this area. One critical aspect that warrants attention is the continuous refinement of VR welding simulations to closely mimic real-world welding scenarios. This involves the incorporation of advanced haptic feedback and realistic visual cues to enhance the immersive experience and practical applicability of VR training.

Moreover, the expansion of VR welding training programs to encompass a wider range of welding techniques and specialised procedures will be vital for ensuring comprehensive skill development among welding practitioners. This expansion should be accompanied by meticulous validation and certification processes to establish the credibility and standardisation of VR welding training across the industry. Another area of prospective research lies in the exploration of augmented reality as a complementary tool to VR welding technology. AR has the potential to overlay digital information onto the physical welding environment, providing real-time guidance and feedback to welders during actual welding tasks. Investigating the synergy between VR and AR in welding practice could pave the way for an integrated and enhanced training approach that maximises both virtual and real-world learning experiences. Furthermore,

it is essential to continuously monitor and analyse the long-term career trajectories of individuals who have undergone VR welding training to assess their sustained proficiency, adaptability, and success in the welding industry. This longitudinal study will offer valuable insights into the enduring impact of VR welding technology on the professional growth and skill retention of welders, enriching the understanding of its role in shaping the industry's workforce dynamics.

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