Exploring Immersive Training in Industrial Organizations

Kirstin Johnson

Department of Education, Baker University

IDPT 5090: Masters Project

Dr. Anna Catterson

April 20, 2024

Abstract

Industrial organizations increasingly see the value of investing in augmented reality and virtual reality training solutions. There is a need to address the gap in traditional training methods, including the inability to practice dangerous procedures, space limitations, and lack of hands-on experience. Immersive technologies like AR and VR have the potential to help industrial organizations overcome challenges and gaps experienced when using traditional training methods. This research seeks to answer the following questions: What are the benefits of using AR and VR in industrial settings, and how do they compare in terms of effectiveness? What are the effects of integrating AR and VR within training programs regarding cost, flexibility, safety, and engagement? What are the key factors and limitations when implementing AR and VR technologies for training in industrial settings?

This review is a comprehensive examination of scholarly journals, articles, case studies, and empirical research from 2010 to 2023 investigating AR and VR technology's benefits in training and its application within manufacturing and other skilled trade environments. Analysis of existing literature revealed that implementing AR and VR technologies in training within industrial settings can significantly enhance learning effectiveness, learner performance, and engagement. The literature also suggests that these solutions can potentially reduce training costs and address safety concerns associated with hazardous environments. It also revealed that the scalability of these technologies makes adoption easier in various environments. Future research should investigate the long-term effects of immersive technologies on effectiveness and the various factors that promote user acceptance during implementation.

Introduction

Augmented Reality (AR) and Virtual Reality (VR) technologies are increasingly being adopted in several industries, including industrial sectors, to enhance training, productivity, and business processes. According to PwC's Seeing is Believing report, AR and VR can potentially add a $1.5 trillion increase to the global economy by 2030, and $294.2 billion will be dedicated toward training. This prediction is reinforced by a 2018 study by Capgemini Research Institute, which surveyed over 700 automotive, manufacturing, and utilities executives and discovered that 50% of the organizations not currently using AR and VR planned to start exploring these technologies within the next three years. Much of this increased interest and growth can be explained by the pandemic's profound transformation in workforce training, compelling organizations to implement immersive technologies(Software Advice, 2021). Software Advice's 2021 study indicates that of the organizations using AR or VR for training, 59% implemented the solutions for the first time during the pandemic, and 86% intend to continue using it. The continued adoption is reflected in Grand View Research's 2023 Market Analysis Report, which forecasts an 18% growth rate per year of VR technology between 2023 and 2030. This literature review aims to compare and analyze the benefits and effects of AR and VR technologies in industrial settings, highlighting each technology's strengths, weaknesses, and potential use cases.

Training in manufacturing settings is crucial to ensure safety and efficiency. Traditional training methods often require learners to leave their jobs and travel to a physical space for training, and if the training is far away, this leads to expensive business travel costs (Garcia et al., 2016). Ellis (2022) revealed dissatisfaction with current learning programs offering basic video and text options and reported that two out of three employees desired more real-life simulations. According to Gamelearn's Contradictions of Corporate Training 2022 report, two-

thirds of companies have increased online learning investments, but employees give those programs a Net Promoter Score of -29. Employees want engaging and immersive training options (Ellis, 2022). Additional gaps in traditional training methods include the inability to practice dangerous procedures, space limitations, and lack of hands-on experience (HQ Software, 2024). AR and VR solutions offer unique advantages over traditional training methods in industrial settings. VR immerses learners in realistic simulations that mimic industrial environments. VR technology has been shown to save training time and resources and eliminate the risks of operating heavy machinery (Dalto, 2018). AR technology overlays digital information on a learner's real-world environment, adding contextual information and task instructions (Software Advice, 2021). Software Advice's 2021 report found that 61% state AR training helps employees comprehend their jobs better. Against this backdrop, this literature review aims to address the following research questions:

1. What are the benefits of using AR and VR in industrial settings, and how do they compare in terms of effectiveness?
2. What are the effects of integrating AR and VR within training programs regarding cost, accessibility, safety, and engagement?
3. What are the key factors and limitations when implementing AR and VR technologies for training in industrial settings?

This literature review comprehensively analyzes scholarly works, case studies, industry reports, and empirical studies from 2010 to 2023. The literature was sourced through an electronic search on several databases, including Google Scholar, ESBCO, and Springer, using the keywords AR, augmented reality, VR, virtual reality, manufacturing, industrial, training, and education. Sources were selected based on their relevance to the research topic and period.

Studies from diverse perspectives, including academia, industry, and technology experts, were considered. The analysis of these sources for inclusion started with a review of titles and abstracts to identify relevant articles. Afterward, the full text was reviewed further to assess each text's quality, findings, insights, and number of citations. This selection process identified a body of literature to shed light on the implications, benefits, and constraints of implementing AR and VR training solutions in industrial settings.

Literature Review

This literature review will begin each section with a definition of AR and VR, describing their unique characteristics. Subsequently, it will delve into the benefits associated with each type. Furthermore, the review will address the considerations and challenges inherent in each type, providing a deeper understanding of their potential constraints. Finally, the review will conclude with future research considerations.

Benefits of Virtual Reality in Training

Virtual reality (VR) is a virtual interactive environment designed to replicate the real world and indicated by two distinct attributes: immersion and presence (Radhakrishnan et al., 2021). Immersion refers to the extent of sensory fidelity achieved by a virtual reality system, while presence encompasses the user's subjective experience within this immersive environment (Radhakrishnan et al., 2021). This involves seamlessly altering the visual display in real time as the viewer's perspective shifts, creating an immersive and dynamic experience (Onyesolu & Eze, 2011). As outlined in the following sections, VR offers numerous advantages, highlighting key trends in the reviewed literature.

Improved Engagement and Effectiveness

Current research on VR highlights its effectiveness when enhancing learner engagement, presence, and immersion. According to Radhakrishnan et al. (2021), VR experiences create an increased sense of immersion, allowing learners to feel like they are truly present in the virtual world, which in turn reduces cognitive load (Radhakrishnan et al., 2021) By wearing a headset or similar hardware, learners are ultimately enabled to become fully immersed in the environment. This effectively isolates the learner from external distractions in the physical world, facilitating a more engaging and focused learning experience (Radhakrishnan et al., 2021). VR's immersive environment holds learners' attention and alleviates cognitive load, creating a better learning experience.

The interactivity of VR is another aspect that enhances its effectiveness in training. Onyesolu and Eze (2011) emphasize that the basis of VR's strength lies in its unique ability to provide learners with the opportunity to interact with information and their environment, a pivotal factor for effective learning. Barkokebas et al. (2019) corroborate these findings by discovering that participants trained with VR outperformed participants trained by conventional learning methods, with VR training reducing task completion time and errors. Additionally, the unique ability to provide opportunities for interactivity helps with learner retention. Krokos et. Al (2018) found in a University of Maryland study that people retain information better when interacting with virtual environments than traditional training methods. All studies revealed that the use of VR technology increased efficiency, retention, and mastery compared to those using traditional instructional materials.

Reduced Training Time

VR technology's ability to decrease training time highlights its efficiency. Pfizer's use of VR emphasized this strength while implementing VR training to get manufacturing workers up to speed, transforming 100-plus pages of training documents into interactive virtual reality training and reducing training time by 40 percent (Goldenberg, 2023). Thus minimizing the space required for training and increasing the quality of training. A 2020 PwC study agrees that VR participants completed training four times faster than classroom participants. Both studies reveal that using VR technology in training reduces time loss due to errors or downtime compared to traditional methods.

Scalability and Cost Reduction

VR training can reduce an organization's training costs. Goldenberg (2023) found that virtual reality programs save companies thousands of dollars annually by reducing attrition, curtailing onboarding, and reducing travel costs to training facilities. Rubenstone (2017) reported that a company has developed a collaborative VR training environment called One Room that can have between two and twenty users working together in any environment they can build, increasing the number of people learning how to operate heavy machinery simultaneously. A 2020 PwC study corroborates this by reporting that VR training matched classroom costs at 375 learners and matched e-learning costs at 1,950 learners. Goldenberg (2023) adds that virtual reality training is scalable because it is easy to add new headsets and create new training scenarios quickly and efficiently from a cost perspective. These studies highlight VR's transformative power to train more workers on a larger scale at a reduced cost.

Increased Safety and Risk Reduction

VR training uniquely allows learners to build skills, gain experience, and reach mastery in a controlled environment. In one use case, Goldenberg (2023) reports that Verizon has been using virtual reality training since 2021 and has found that associates gain experience and confidence in their skills in a safe, virtual environment. Additionally, Rubenstone (2017) supports this finding within the skilled trade field, where virtual reality training can safely train someone new to use aerial work platforms in a virtual environment and get them ready to work in the field instead of training on a real platform. Both use cases highlight VR technology's ability to ensure an employee's readiness for work without the risks of training in the actual environments.

Benefits of Augmented Reality in Training

Depending on the need, augmented reality integrates the physical world with computer-generated content such as audio, graphics, video, or animation (Kong et al., 2022). Smartphones, tablets, smart glasses, and AR headsets are all devices that can use AR. AR also offers numerous advantages, as outlined in the following section, highlighting key trends observed in the reviewed literature.

Improved Effectiveness and Engagement

AR offers a unique way for learners to build connections between training and the real world, improving effectiveness. Software Advice's 2021 report found that 61% state AR training helps employees comprehend their jobs better, 51% state AR creates a practicality layer to training that helps employees, and 35% state AR helps employees learn faster. Furthermore, the design of AR requires learner engagement. Kong et al., 2022 describe AR as digital information

superimposed on a physical environment, so the interactivity between virtual and real objects is required. Both authors support that AR fosters a deeper connection between the physical and virtual world, enhancing learner engagement and comprehension.

Reduced Training Time and Errors

Because AR can be superimposed on the physical world, it has the opportunity to become an effective training and performance support tool, reducing time to get up to speed and errors. A 2018 Capgemini study found that Boeing uses AR to provide technicians with instructions in their field of view, allowing them to complete tasks hands-free. This use case reduced production time by 25%, increased productivity by 40%, and reduced errors to zero. AR's potential increases an organization's ability to embed training within workflows. Using smart glasses to deliver standard operation procedures (SOP) one step at a side-by-side while an employee completes tasks increases speed and performance (Dalto, 2018). Both studies conclude AR technology can reduce errors and training time while improving performance.

Cost-effectiveness and Scalability

AR can reduce training and resource costs associated with traditional methods. Al-Ansi et al. (2023) report that the use of AR can reduce costs associated with producing learning materials and travel, making it more accessible for anyone while making it affordable. Additionally, AR also reduces the need for physical space. HQ Software (2024) found that AR removes the need for classroom space and multiple instructors by accessing training through AR-enabled devices anywhere, even at home. Both studies conclude that AR technology can reduce training costs associated with traditional methods and alleviate in-house resource constraints.

Safety and Risk Reduction

AR allows organizations to monitor learner processes when working on machinery. Gabajova et al. (2019) confirm that integrating AR technology with equipment allows manufacturing environments to monitor progress and lower risks by continuously monitoring the learner's performance. Additionally, AR can include critical checkpoints to promote safety. Dalton (2018) suggests that safety checkpoints can be embedded in work instructions, requiring workers to confirm that the proper safety protocols are followed. Both studies confirm that AR technology can improve the safety of equipment and learners.

Effectiveness Comparison

Research supports that AR and VR technologies enhance their effectiveness in training. Gabajova et al. (2019) reviewed the training times of an assembly line and found that both AR and VR reduced training times compared to traditional methods. There was no difference between the AR and VR designs. Additionally, several other studies found that the performance of participants using AR and VR training was equal to or even better than participants using traditional training methods (Daling et al., 2023; DaValle & Azhar, 2020; Kwiatek et al., 2019; Koumaditis et al., 2020). These studies confirm that AR and VR technologies potentially increase learning effectiveness.

Challenges and Limitations

While immersive technologies present many benefits, there are challenges associated with implementing them within training contexts. This section outlines the limitations and considerations associated with implementation.

Accessibility

While immersive technologies are gaining popularity, organizations must consider device accessibility. Not all employees will have access to devices, so organizations must provide learners with the necessary equipment (Biswas et al., 2021).

Skill and Cost Investment

Although advancements in immersive technology have lowered the skill and cost barriers for constructing virtual environments, there remains a significant demand for investment in time, upskilling in-house resources, and money. (Onyesolu & Eze, 2011). VR technology offers high interactivity, immersion, presence, and realism. This requires a high level of advanced hardware and software for implementation, and this cost limits its use in various applications (Garcia et al., 2016).

Technology Limitations

To ensure successful immersive learning experiences, hardware is required for the training to succeed. If the equipment is misconfigured, it can lead to delayed response times and presence issues, compromising the reality of the simulation (Onyesolu & Eze, 2011). Immersive approaches also require building and housing hardware in the workplace, reducing its accessibility outside the workplace (Garcia et al., 2016). Organizations must budget and plan for this when implementing these solutions at multiple locations. Latency issues can emerge from bandwidth issues when immersive training is distributed over a network or the internet (Onyesolu & Eze, 2011).

Recommendation

Based on the insights learned from the literature reviewed, the following recommendations are proposed to optimize the successful implementations of immersive technologies in training.

Invest in Development

Dedicate resources to create high-quality AR and VR learning solutions, including interactive scenarios and real-world simulations. Partner with subject matter experts to ensure the information is accurate and relevant. Consider upskilling development teams to create the content in-house.

Prioritize User Experience

Design solutions that create a good user experience, ensuring the design is easy to navigate, engaging, and the ideal environment for learning. Use pilots to test the training and incorporate stakeholder and learner feedback to improve the design before implementation.

Evaluate Effectiveness

Develop an evaluation process to continuously monitor how well the training improves learning outcomes and performance. Gather learner and stakeholder feedback for future enhancements.

Conclusion

This literature review offers valuable insights into the benefits of AR and VR in manufacturing organizations. Both solutions offer unique benefits regarding learning effectiveness, cost-effectiveness, accessibility, and safety. VR offers unparalleled immersion, engagement, and realism while reducing the cognitive load and enhancing the overall learning experience through hardware. However, AR offers the potential to embed training and

performance support tools in the workflow. Organizations may consider a blend of AR and VR if they have various learning needs that would benefit from the strengths of both solutions. Investing in the benefits and implications of these technologies is helpful as they can enhance training initiatives and overcome training, ensuring the optimal delivery of virtual training solutions within the manufacturing industry.

Suggestions for Future Research

While the literature reviewed revealed the potential benefits of implementing AR and VR training solutions in industrial sectors, there is still more that can be learned through future research. Future research should measure the long-term effects of AR and VR training, precisely measuring effectiveness and retention to determine if it impacts overall employee performance, satisfaction, retention, and the organization's growth and profitability. This will give insight into the program's overall return on investment. Future research should also investigate various factors affecting successful implementation within industrial organizations. Specifically, it examines aspects like user experience, quality of the modules, module reliability, and value. This will give insight into designing and implementing training that users will accept and enhance training outcomes.

References

Al-Ansi, A. M., Jaboob, M. M., Garad, A., & Al-Ansi, A. (2023). Analyzing augmented reality (AR) and virtual reality (VR) recent development in education. *Social Sciences & Humanities Open, 8*(1), 2590-2911. https://doi.org/10.1016/j.ssaho.2023.100532

Barkokebas, R., Ritter, C., Sirbu, V., Li, X., & Al-Hussein, M. (2019). Application of virtual reality in task training in the construction manufacturing industry. *Isarc. Proceedings of the International Symposium on Automation and Robotics in Construction, 36,* 796-803. https://www.researchgate.net/profile/Regina-Dias-Barkokebas/publication/336444652_Application_of_Virtual_Reality_in_Task_Training_in_the_Construction_Manufacturing_Industry/links/5da8925e299bf1c1e4c99d2a/Application-of-Virtual-Reality-in-Task-Training-in-the-Construction-Manufacturing-Industry.pdf

Biswas, P., Orero, P., Swaminathan, M., Krishnaswamy, K., & Robinson, P. (2021, May 8). *Adaptive accessible AR/VR systems* [Poster presentation]. 2021 CHI conference on human factors in computing systems (CHI EA '21). Association for Computing Machinery, New York, NY, United States, (92), 1–7. https://doi.org/10.1145/3411763.3441324

Burkhalter, M. (2022, May 19). The five kinds of virtual reality. *Perle*. https://www.perle.com/articles/the-five-kinds-of-virtual-reality-40194293.shtml

Capgemini Research Institute. (2018a). *Augmented and virtual reality in operations.* https://www.capgemini.com/wp-content/uploads/2018/09/AR-VR-in-Operations1.pdf

Capgemini Research Institute. (2018b, September 7). *Immersive technology has arrived: AR and VR set to become mainstream in business operations in the next 3 years.*

https://www.capgemini.com/news/press-releases/immersive-technology-has-arrived-ar-and-vr-set-to-become-mainstream-in-business-operations-in-the-next-3-years/#_ftn3

Daling, L. M., Tenbrock, M., Isenhardt, I., & Schlittmeier, S. J. (2023). Assemble it like this! – Is AR- or VR- based training an effective alternative to video-based training in manual assembly?. *Applied Ergonomics, 110*. https://doi.org/10.1016/j.apergo.2023.104021

Dalto, J. (2018, September 1). AR, VR, and 3-D can make workers better. *ISE Magazine*. https://web-p-ebscohost-com.bakeru.idm.oclc.org/ehost/pdfviewer/pdfviewer?vid=10&sid=11e76b1e-dc7a-42db-9c46-459e1a1ce3a6%40redis

DaValle, A. & Azhar, S. (2020). *An investigation of mixed reality technology for onsite construction assembly* [Poster presentation]. MATEC Web Conference 312 (06001). https://doi.org/10.1051/matecconf/202031206001

Ellis, R. K. (2022, November 1). Game over for basic e-learning. *TD: Talent Development, 76*(11), 10. https://www.td.org/magazines/td-magazine/game-over-for-basic-e-learning

Gabajová G., Furmannová, B., Medvecká, I., Grznár, P., Krajčovič, M., & Furmann, R. (2019). Virtual training application by use of augmented and virtual reality under university technology enhanced learning in Slovakia. *Sustainability*, *11*(23), 6677. https://doi.org/10.3390/su11236677

Garcia, A. A., Bobadilla, I. G., Figueroa, G. A., Ramirea, M. P., & Roman, J. M. (2016, March). Virtual reality training system for maintenance and operation of high-voltage overhead power lines. *Virtual Reality 20*, 27-40. DOI10.1007/s10055-015-0280-6

Goldenberg, B. (2023, November 20). VR training is replacing traditional sales and customer service training. *CRM Magazine*, *27*(9), 4-5.

https://www.destinationcrm.com/Articles/Columns-Departments/Customer-Experience/VR-Training-Is-Replacing-Traditional-Sales-and-Customer-Service-Training-161526.aspx

Grand View Research. (2023, July 19). *Virtual reality (VR) market size, share & trends analysis report by technology (Semi & fully immersive, non-immersive), by device (HMD, GTD), by component (Hardware, software), by application, by region, and segment forecasts, 2023 – 2030.* https://www.grandviewresearch.com/industry-analysis/virtual-reality-vr-market

HQ Software. (2024, January 19). *Benefits of using AR and VR in employee training*. https://hqsoftwarelab.com/blog/ar-vr-training-benefits/

Kwiatek, C., Sharif, M., Li, S., Haas, C., & Walbridge, S. (2019). Impact of augmented reality and spatial cognition on assembly in construction. *Automation in Construction, 108*(102935). https://doi.org/10.1016/j.autcon.2019.102935

Kong, X., Fegely, A., De Backer, W., Gray, M., Hitt, G. & Kerns, R. (2022, June). *Work-in-progress: Developing an interactive, immersive, 360-degree virtual media for enhancing student learning in additive manufacturing* [Poster presentation]. 2022 ASEE Annual Conference & Exposition, Minneapolis, Minnesota, United States. DOI:10.18260/1-2--41843

Koumaditis, K., Chinello, F., Mitkidis, P., & Karg, S. (2020, July 1). Effectiveness of virtual versus physical training: The case of assembly tasks, trainer's verbal assistance, and task complexity. *IEEE Computer Graphics and Applications. 40*(5), 41–56. DOI: 10.1109/MCG.2020.3006330

Krokos, E., Plaisant, C., & Varshney, A. (2018, May 3). Virtual memory palaces: Immersion aids recall. *Virtual Reality*. https://obj.umiacs.umd.edu/virtual_reality_study/10.1007-s10055-018-0346-3.pdf

Navarrete, S. (2021, September 30). *AR and VR are used by 40% of SMEs for training.* Software Advice. https://www.softwareadvice.co.uk/blog/2236/ar-in-training-now-used-by-40

Onyesolu, M. O., & Eze, F. U. (2011). Understanding virtual reality technology: Advances and applications. In M. Schmidt (Eds.), *Advances in computer science and engineering* (4). InTechOpen. https://doi.org/10.5772/15529

PwC Global. (2019). *Seeing is believing.* https://www.pwc.com/gx/en/technology/publications/assets/how-virtual-reality-and-augmented-reality.pdf

PwC Global. (2020, June 25). *The effectiveness of virtual reality soft skills training in the enterprise: A study.* https://www.pwc.com/us/en/services/consulting/technology/emerging-technology/assets/pwc-understanding-the-effectiveness-of-soft-skills-training-in-the-enterprise-a-study.pdf

Radhakrishnan, U., Koumaditis, K., & Chinello, F. (2021). A systematic review of immersive virtual reality for industrial skills training. *Behaviour & Information Technology*, *40*(12), 1310-1339. https://doi-org.bakeru.idm.oclc.org/10.1080/0144929X.2021.1954693

Rubenstone, J. (2017, October 17). Virtual reality finds a nice in skilled trade education. *ENR*. https://www.enr.com/articles/43113-virtual-reality-finds-a-niche-in-skilled-trades-education