Proceedings of the International Conference on Industrial Engineering and Operations Management

Publisher: IEOM Society International, USA DOI: 10.46254/GC02.20240181
Published: December 01, 2024

An Insight into Prevalence of eXtended Reality in Different Industrial Sectors of Saudi Arabia

Fahad Alasim
Assistant Professor
Industrial Engineering Department
College of Engineering
King Saud University
Riyadh-11421, Saudi Arabia
Vice-Dean
Advanced Manufacturing Institute
King Saud University
Riyadh-11421, Saudi Arabia
falasim@ksu.edu.sa

Abstract

The advent of the fourth industrial revolution has an impact on the majority of domains and industries. In the manufacturing industry, it is usually referred to as Industry 4.0. Virtual and augmented reality (VR/AR), is the one of the nine pillars that is garnering a lot of interest worldwide. It is an intriguing technology which has proven benefits in several domains such as healthcare, teaching, training, etc. Since VR, AR, and mixed reality are all closely related, the term used to describe them all together is eXtended reality. Specially for the developing nations these technologies are very useful. Therefore, it is very important to know about these technologies' applications and their prevalence. As a result, a study has been done in this research work to gain an understanding of its appeal in Saudi Arabia's various industrial sectors. The data was collected using surveys and expert interviews. The data was analyzed statistically and it is reported that eXtended reality technologies are gaining popularity and people are using it more in the field of entertainment. Moreover, big firms in oil and gas sector have employed it, however small and medium enterprises(SMEs) are lagging behind. In the academics and education establishments, its presence is there from a long time. Moreover, there are quite a few medical organizations that are utilizing these technologies. It can be concluded based on the results that more training and familiarization programs and courses are required by the academic and training institute to harness the benefits of these captivating technologies.

Keywords

Augmented reality, Industry 4.0, Mixed reality, Saudi Arabia, Virtual reality.

1. Introduction

The Fourth Industrial Revolution, commonly referred to as Industry 4.0, denotes the incorporation of highly advanced technologies including the Internet of Things (IoT), artificial intelligence (AI), and eXtended Reality (XR) into industrial operations (Salah et al. 2019). This revolution is transforming conventional manufacturing and service industries, resulting in enhanced efficiency and production.

Over the past few years, the use of XR, a term that includes Augmented Reality (AR), Virtual Reality (VR), and Mixed Reality (MR), has become very common across various industrial sectors (Jagatheesaperumal et al. 2024). XR signifies a technology frontier that enriches user experiences via immersive interactions. XR applications have

demonstrated significant advantages in multiple sectors, such as healthcare for surgical training (Lang et al. 2024), manufacturing (Chu and Pan 2024), education for interactive learning experiences (Hamash et al. 2024), and training simulations across various industries (Abidi et al. 2019). However, XR's application in different sectors has brought a number of opportunities and challenges as well. It has helped organizations improve their operational efficiencies, for training operations, and for fast showcasing of products from prototypes (Abidi et al. 2016, Al-Ahmari et al. 2016). The primary objective of this research work is to realize the use and importance of XR in various sectors in Saudi Arabia. This study seeks to evaluate the prevalence and applicability of XR technologies in several industrial sectors in Saudi Arabia, emphasizing their current utilization and potential for future expansion. Since last decade, aspects of XR's application in various industrial sectors of Saudi Arabia and its adoption factors have been discussed significantly (Abidi et al. 2013, Alhumaidi et al. 2023). The various industrial sectors that have been covered include the educational sector, the healthcare sector, and the cultural heritage industry (Alqutaibi et al. 2024). Other studies on the telecommunications sector and a detailed description of the banking sector in Saudi Arabia have also been discussed significantly.

Saudi Arabia, also known as the Kingdom of Saudi Arabia (KSA), is an oil-based country that is a significant contributor to the world's energy resources. A range of industries exists in the economy of Saudi Arabia, such as petroleum, agriculture, driving, and trading. It has abundant underground oil reserves, and petroleum exports significantly drive its economy. Besides, there are numerous other industrial sectors also contributing significantly to Saudi Arabia's GDP (Gross Domestic Product), such as telecommunications, real estate, and tourism. As part of Vision 2030, the Saudi Arabian technology revolution is used to encourage and promote industrial growth (KSA Vision 2030 2016). The Saudi government and government institutions have been driving forces for technological integration. One of the compelling features of XR is bridging the gap between physical production and its digital reproduction. Through XR applications, space, museum curators, designers, historians, and scientists can work on innovative digital designs at various phases of digital development (Riyadh Valley Co. 2024). The immediate experience of the multiple virtual re-expositions of a museum setup allows one to pick the desired one by applying XR technology. Although the Saudi economy is highly dependent on the petroleum and crude oil industry, the government has realized the importance of diversifying the sectors in the economy and has started pushing other fields, such as minerals exploration and trade, as part of the Saudi 2030 vision. The use of technology in different fields provides a string of various uses and gains. Thus, based on literature, it can be seen that there is a gap in having a real time information about the usage and prevalence of XR in Saudi Arabia. This research work holds the primary objective of analyzing the use of XR in different industries within the kingdom. The research work studies the various issues in the adoption and real-time implementation of XR across the sectors.

2. Overview of eXtended reality (XR) technologies

Extended Reality (XR) is a family of cutting-edge technologies that encompasses Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR) (Curran et al. 2023). VR takes its users into an entirely digital environment usually by the use of a headset with a 3D screen, enhancing auditory senses with the help of surround sound that simulates the user’s movement in that environment (Abidi et al. 2018). AR/MR, on the other hand, are based on the integration of spatial, physical, and digital realities, where an AR/MR application works by projecting virtual information on top of a real-world organization and can also appear as if they are interactive three-dimensional objects, resulting in a new environment (Holt 2023). AR is composed of two main elements: hardware that provides the technology to connect between the real and virtual worlds and software that processes the simulation using selected platforms based on application requirements (Dargan et al. 2023). In contrast, the technology component needed for AR implementation is a little bit less than that of VR.

XR has been in development for several decades, with the inception of VR first occurring in the year 1968 and more recently after becoming a reality with the portable and affordable VR devices introduced during last decade and becoming a household name (Wohlgenannt et al. 2020). The second generation of augmented reality took effect in six years; MR is in its infant stages. Many of these new technologies have been used in various sectors, such as tourism, health, entertainment, art, architecture, automotive, manufacturing, and other engineering field applications (Holt 2023). Through MR advances, engineers are now able to walk through vehicles in production and conduct in-depth inspections of systems ranging from brake lines to air conditioners, frame straightness, hooks, and mechanicals, and other parts of a vehicle (Koyachi et al. 2023). All these things were once thought to be impossible in reality. It was only possible based on our recent experiences and advances in XR technology that made it possible. The probability

of damage occurrence has increased, and the time factor has also decreased significantly, prompting major companies to employ these technologies, which have had an impact in virtually every sector today.

XR as the emerging technology is transforming the way of doing business. The adoption of XR in various industries, such as healthcare, manufacturing, construction, transportation, and education, is providing multiple scientific and commercial benefits (Khan 2023). XR is now being implemented in multiple healthcare domains for the purpose of training, diagnosis, preoperative care, and therapy (Vyas 2023). In the education and training fields, XR has been implemented for presenting complex science stories, chemical reactions, basic concepts, such as the education of science, and for historical events, 3D organisms, and space viewing (Aguayo and Eames 2023). In manufacturing and design, XR has been used for product design, prototyping, and development (Abidi et al. 2012). Similarly, XR-based systems have been implemented in construction, which are further divided into fields like maintenance and inspection, remote assistance, worker training, planning and managing construction, and facilities and engineering management. Therefore, it is important to investigate the utilization of the XR technologies across KSA in different industrial sectors.

3. Methodology

3.1 Research Design

This study utilized a mixed-methods approach, integrating qualitative and quantitative research to obtain extensive insights into the prevalence of XR technology across several sectors.

3.2 Data Collection

Data was collected through:

Surveys*:* Administered to employees and decision-makers across several industrial sectors to evaluate their awareness and utilization of XR technologies.

Expert Interviews: Engaged with industry professionals and academics to obtain comprehensive insights on XR applications.

A total of 150 participants responded to the survey questions (survey is provided in the appendix after references).

3.3 Data Analysis

The collected data were analysed using statistical methods, including descriptive statistics to summarize survey responses and thematic analysis for interview data, highlighting key trends and insights.

4. Results

4.1 Descriptive Statistics

This section shows the results obtained from the statistical analysis of the respondent data.

The familiarity with the XR technology shows that a significant portion of respondents (39.33%) have some level of familiarity with XR, while a substantial number (35.33%) are not familiar at all, indicating an awareness gap that can be targeted with training programs. The Oil & Gas sector leads in XR adoption with a 70.59% usage rate, followed closely by the Healthcare sector. Education/Academia has a lower adoption rate, with 54.84% of respondents indicating no XR usage, signifying potential growth areas for XR application. Industries vary in their adoption of XR, with sectors like Entertainment and Oil & Gas showing higher usage compared to SMEs and others.

Major challenges faced in implementing XR are summarized in Figure 1. The most frequently cited challenges are Limited Expertise, Skilled Workforce, and High Cost of Equipment and Technology, indicating key barriers to further

XR adoption. By analyzing distinct advantages and problems within each business, strategic advice can be customized to address barriers to XR adoption in sectors such as SMEs.

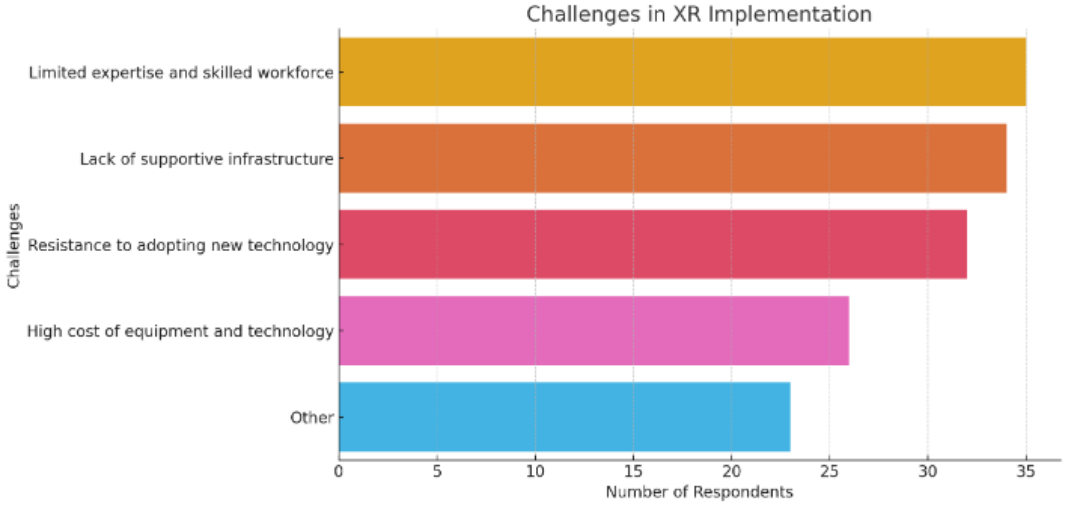

Figure 1. Major challenges in XR implementation

Figure 2 shows the interest in additional XR training.

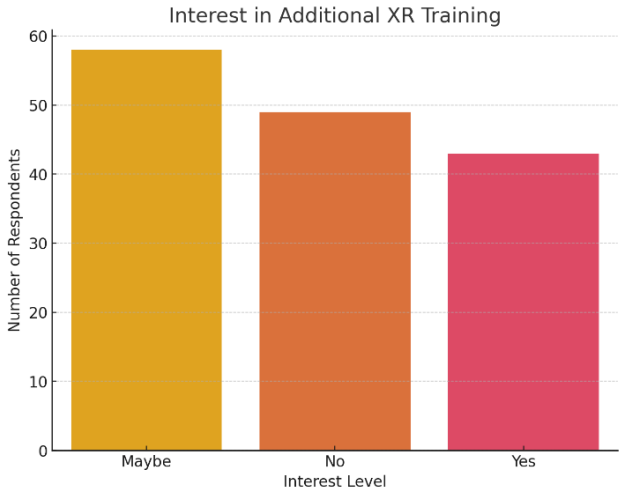

Figure 2. Interest in Additional XR Training.

In terms of benefits of using XR, the following data has been obtained as shown in Table 1.

Table 1. Benefits observed from XR

Benefit	Percentage (%)
Increased operational efficiency	26.00
Enhanced employee skills and training	24.67
Improved customer experience	18.67
Cost savings	17.33
Other	13.33

The most commonly cited benefit is increased operational efficiency (26.00%), followed by enhanced employee skills and training (24.67%), indicating that XR is seen as valuable for productivity and skill enhancement.

4.2 Cross-Tabulations and Comparative Analysis

This section shows cross tabulations between various responses for comparative analysis.

Figure 3 shows the familiarization of XR across various industries. Oil & Gas respondents are largely somewhat familiar with XR. Entertainment respondents report high familiarity. Education/Academia and Healthcare respondents exhibit a moderate level of familiarity.

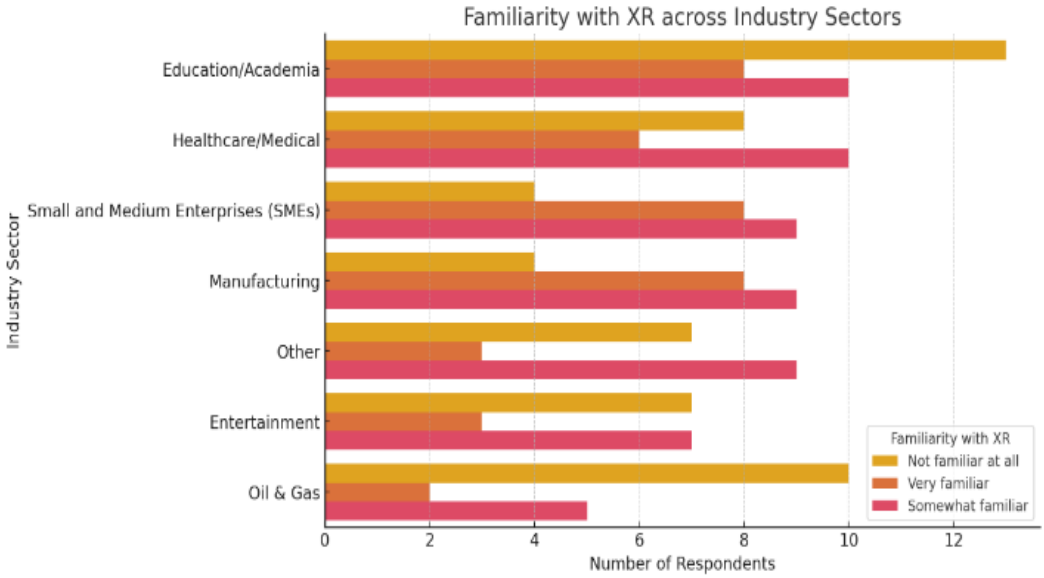

Figure 3. Familiarity of XR across various industrial sectors.

Similarly, XR usage by the industry shows the following results (Table 2). As seen from Table 2, XR usage in oil and gas industry is relatively at higher side. This can be due to large organisations available in KSA in this sector which possess better infrastructure, research and development centres, as well as good capital. Moreover, due to the risk environments, their operational needs also requires technology such as XR.

Table 2. XR Usage by Industry

Industry Sector	**XR Usage: No (%)**	**XR Usage: Yes (%)**
Education/Academia	54.84	45.16
Entertainment	52.94	47.06
Healthcare/Medical	50.00	50.00
Manufacturing	52.38	47.62
Oil & Gas	29.41	70.59
Other	47.37	52.63
Small and Medium Enterprises	47.62	52.38

Figure 4 shows the primary usage of XR across various industries. The primary purpose of XR utilization is predominantly focused on employee training and skill development, as well as operations and maintenance, indicating that practical applications outweigh design and consumer engagement purposes. Diverse industries emphasize XR for distinct objectives: staff training in healthcare and oil and gas, customer engagement in entertainment, and marketing in small and medium enterprises. These findings highlight the diverse value that XR provides based on the specific needs and aims of the industry.

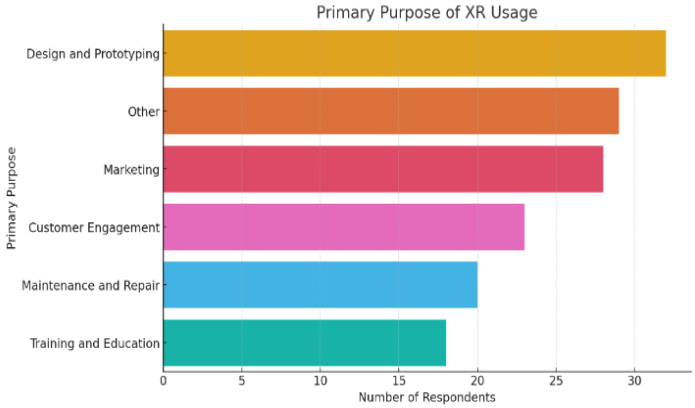

Figure 4. Primary usage of XR in various industries.

Table 3, shows the interest in additional XR training by familiarity level. Individuals with greater familiarity exhibit an increased interest in further training, as seen by a 44.74% "Maybe" answer rate among those who are "Very familiar," suggesting a desire for more profound learning among already-engaged users. From further analysis of the data, it is observed that a significant proportion of respondents, particularly in the Oil & Gas and Manufacturing sectors, express interest in further training, indicating a willingness for skill development efforts.

Table 3. Interest in Additional XR Training by Familiarity Level

Familiarity Level	Maybe (%)	No (%)	Yes (%)
Not familiar at all	33.96	37.74	28.30
Somewhat familiar	38.98	30.51	30.51
Very familiar	44.74	28.95	26.32

4.3 Correlation Analysis

Spearman correlation was utilized to evaluate the correlations among the different category responses in the survey data. Spearman correlation is a non-parametric metric of rank correlation that assesses the strength and direction of the relationship between two variables without assuming a certain frequency distribution of the data. This renders it especially advantageous for ordinal data, such as survey responses. The correlation matrix was computed utilizing Python's pandas module, and the visualization was produced with the seaborn and matplotlib tools. Figure 5 shows the heatmap for the correlation analysis.

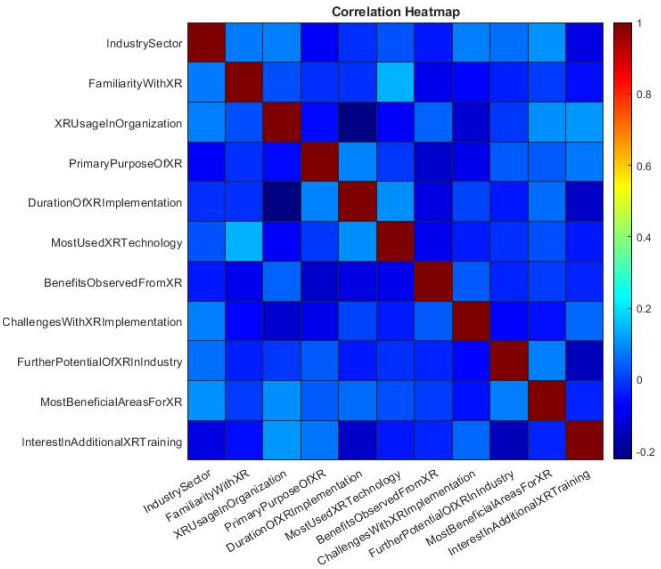

Figure 5. Correlation analysis heatmap.

5. Discussion and Conclusions

This study provides insights into the acceptance and perception of extended reality (XR) technologies within Saudi Arabia's industrial sectors, highlighting specific trends in familiarity, usage, and problems that influence XR's deployment.

This report emphasizes the encouraging but inconsistent implementation of XR across various industry sectors in Saudi Arabia. Elevated adoption rates in industries such as oil and gas, healthcare, and entertainment validate XR's adaptability and capacity to foster innovation. Nonetheless, diminished familiarity and acceptance within SMEs and academia suggest that enhanced awareness and assistance are crucial to promote wider use across many industries. SMEs lag behind in the usage due to lack of knowledge as well as the management think it as an extra burden on the company's finance. However, with proper implementation strategy XR can be profitable in longer run.

Major findings of the study reveal:

1. Operational efficiency and employee skill enhancement are the most significant benefits, especially for industries with complex workflows and training needs.
2. Limited expertise, infrastructure, and cost constraints are prominent challenges, particularly in resource-constrained industries like SMEs and academia.
3. The need for targeted training programs is crucial, as familiarity with XR directly correlates with a willingness to engage in further training.

XR technologies possess significant potential to propel Industry 4.0 developments in Saudi Arabia; yet, widespread adoption necessitates coordinated efforts to address implementation issues. Policymakers, industry leaders, and educational institutions ought to pursue joint initiatives to enhance accessibility to XR technologies, provide subsidized training, and provide XR infrastructure that accommodates the requirements of many industries. Through smart investment and information distribution, XR can significantly enhance Saudi Arabia's status as a leader in regional digital transformation.

References

Abidi, M. H., A. Ahmad, A. M. El-Tamimi and A. M. Al-Ahmari. Development and Evaluation of a Virtual Assembly Trainer, *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, vol. 56, no. 1, pp. 2560-2564, 2012.

Abidi, M. H., A. Al-Ahmari, A. Ahmad, W. Ameen and H. Alkhalefah. Assessment of virtual reality-based manufacturing assembly training system, *The International Journal of Advanced Manufacturing Technology*, vol. 105, no. 9, pp. 3743-3759, 2019.

Abidi, M. H., A. M. Al-Ahmari, A. Ahmad, S. Darmoul and W. Ameen. Semi-Immersive Virtual Turbine Engine Simulation System, *International Journal of Turbo & Jet-Engines*, vol. 35, no. 2, pp. 149-160, 2018.

Abidi, M. H., A. M. Al-Ahmari, A. M. El-Tamimi, S. Darwish and A. Ahmad. Development and Evaluation of the Virtual Prototype of the First Saudi Arabian-Designed Car, *Computers*, vol. 5, no. 4, pp. 26, 2016.

Abidi, M. H., A. M. El-Tamimi, A. M. Al-Ahmari, S. M. Darwish and M. S. Rasheed. Virtual Ergonomic Assessment of First Saudi Arabian Designed Car in a Semi-Immersive Environment, *Procedia Engineering*, vol. 64, no., pp. 622-631, 2013.

Aguayo, C. and C. Eames. Using mixed reality (XR) immersive learning to enhance environmental education, *The Journal of Environmental Education*, vol. 54, no. 1, pp. 58-71, 2023.

Al-Ahmari, A. M., M. H. Abidi, A. Ahmad and S. Darmoul. Development of a virtual manufacturing assembly simulation system, *Advances in Mechanical Engineering*, vol. 8, no. 3, pp. 1687814016639824, 2016.

Alhumaidi, W. A., N. N. Alqurashi, R. D. Alnumani, E. S. Althagafi, F. R. Bajunaid and G. O. Alnefaie. Perceptions of Doctors in Saudi Arabia Toward Virtual Reality and Augmented Reality Applications in Healthcare, *Cureus*, vol. 15, no. 7, pp. e42648, 2023.

Alqutaibi, A. Y., H. H. Hamadallah, H. F. Oqbi, S. A. Almuzaini and S. Borzangy. Current applications and future perspective of virtual reality in dental education and practice in Saudi Arabia: A scoping review, *The Saudi Dental Journal*, no., 2024.

Chu, C.-H. and J.-K. Pan. A Systematic Review on Extended Reality Applications for Sustainable Manufacturing Across the Product Lifecycle, *International Journal of Precision Engineering and Manufacturing-Green Technology*, vol. 11, no. 3, pp. 1017-1028, 2024.

Curran, V. R., X. Xu, M. Y. Aydin and O. Meruvia-Pastor. Use of Extended Reality in Medical Education: An Integrative Review, *Medical Science Educator*, vol. 33, no. 1, pp. 275-286, 2023.

Dargan, S., S. Bansal, M. Kumar, A. Mittal and K. Kumar. Augmented Reality: A Comprehensive Review, *Archives of Computational Methods in Engineering*, vol. 30, no. 2, pp. 1057-1080, 2023.

Hamash, M., H. Ghreir and P. Tiernan. Breaking through Barriers: A Systematic Review of Extended Reality in Education for the Visually Impaired, *Education Sciences*, vol. 14, no. 4, pp. 365, 2024.

Holt, S. Virtual reality, augmented reality and mixed reality: For astronaut mental health; and space tourism, education and outreach, *Acta Astronautica*, vol. 203, no., pp. 436-446, 2023.

Jagatheesaperumal, S. K., K. Ahmad, A. Al-Fuqaha and J. Qadir. Advancing Education Through Extended Reality and Internet of Everything Enabled Metaverses: Applications, Challenges, and Open Issues, *IEEE Transactions on Learning Technologies*, vol. 17, no., pp. 1120-1139, 2024.

Khan, S. *Chapter One - Extended reality: bringing the 3Rs together*. Extended Reality for Healthcare Systems. S. Khan, M. Alam, S. A. Banday and M. S. Usta, Academic Press, pp. 1-13, 2023.

Koyachi, M., K. Sugahara, K. Tachizawa, A. Nishiyama, K. Odaka, S. Matsunaga, M. Sugimoto and A. Katakura. Mixed-reality and computer-aided design/computer-aided manufacturing technology for mandibular reconstruction: a case description, *Quant Imaging Med Surg*, vol. 13, no. 6, pp. 4050-4056, 2023.

KSA Vision 2030 (2016) "Saudi Vision 2030." DOI: https://www.vision2030.gov.sa/media/rc0b5oy1/saudi_vision203.pdf.

Lang, M., S. Ghandour, B. Rikard, E. K. Balasalle, M. R. Rouhezamin, H. Zhang and R. N. Uppot. Medical Extended Reality for Radiology Education and Training, *Journal of the American College of Radiology*, vol. 21, no. 10, pp. 1583-1594, 2024.

Riyadh Valley Co. (2024) "Augmented Reality and Virtual Reality – Imperative for e-learning." DOI: https://rvc.com.sa/wp-content/uploads/2024/02/Augmented-Reality-Virtual-Reality-%E2%80%93-Imperative-for-e-learning_27-02-2024.pdf.

Salah, B., M. H. Abidi, S. H. Mian, M. Krid, H. Alkhalefah and A. Abdo. Virtual Reality-Based Engineering Education to Enhance Manufacturing Sustainability in Industry 4.0, *Sustainability*, vol. 11, no. 5, pp. 1477, 2019.

Vyas, S. *Chapter Twelve - Extended reality and edge AI for healthcare 4.0: systematic study*. Extended Reality for Healthcare Systems. S. Khan, M. Alam, S. A. Banday and M. S. Usta, Academic Press, pp. 229-240, 2023.

Wohlgenannt, I., A. Simons and S. Stieglitz. Virtual Reality, *Business & Information Systems Engineering*, vol. 62, no. 5, pp. 455-461, 2020.

Biography

Fahad Alasim is an Assistant Professor in the Industrial Engineering Department at King Saud University (KSU), and he currently serves as the Vice Dean of the Advanced Manufacturing Institute at King Saud University. He received his B.S. in Industrial Engineering from KSU, and M.S. in Industrial Engineering from University of Central Florida (UCF). In addition, Dr. Alasim received a Ph.D. in Industrial Engineering from UCF. His research interests include operations management, artificial intelligence, simulation, virtual reality, and advanced manufacturing.

Appendix

Survey Questionnaire

Part A: General Information

1. **Please select your industry sector**:
   - Manufacturing
   - Oil & Gas
   - Education/Academia
   - Healthcare/Medical
   - Entertainment
   - Small and Medium Enterprises (SMEs)
   - Other (Please specify): _____
2. **How familiar are you with Extended Reality (XR) technologies (including VR, AR, and MR)?**
   - Very familiar
   - Somewhat familiar
   - Not familiar at all
3. **Have you used XR technologies in your organization?**
   - Yes

- No

Part B: Usage and Applications

4. **What is the primary purpose of XR technology in your organization? (Select all that apply)**
   - Training and Education
   - Design and Prototyping
   - Maintenance and Repair
   - Customer Engagement
   - Marketing
   - Other (Please specify): _____
5. **How long has XR been implemented in your organization?**
   - Less than a year
   - 1-3 years
   - More than 3 years
   - Not applicable
6. **Which XR technology is most widely used in your organization?**
   - Virtual Reality (VR)
   - Augmented Reality (AR)
   - Mixed Reality (MR)
   - Combination of VR/AR/MR
   - None

Part C: Benefits and Challenges

7. **What benefits have you observed from using XR in your organization? (Select all that apply)**
   - Increased operational efficiency
   - Enhanced employee skills and training
   - Improved customer experience
   - Cost savings
   - Other (Please specify): _____
8. **What challenges does your organization face with XR implementation? (Select all that apply)**
   - High cost of equipment and technology
   - Limited expertise and skilled workforce
   - Resistance to adopting new technology
   - Lack of supportive infrastructure
   - Other (Please specify): _____

Part D: Future Potential

9. **Do you believe XR has further potential in your industry?**
   - Yes
   - No
   - Unsure
10. **Which areas would benefit most from further XR integration in your industry?**
    - Employee training and skill development
    - Product design and development
    - Sales and marketing
    - Operations and maintenance
    - Other (Please specify): _____
11. **Would you be interested in additional training or courses on XR technology?**
    - Yes
    - No
    - Maybe
12. **Additional comments or suggestions for promoting XR in your industry:**
