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A REVIEW ON RECENT TRENDS AND CHALLENGES OF VIRTUAL IMMERSIVE LEARNING IN ENGINEERING EDUCATION

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Abstract

Teaching and learning process is facing new challenges in the twenty-first century and adaptations are needed to meet current situations and requirements. With the advancements of technologies in Industrial Revolution 4.0 (IR4.0) such as Augmented Reality (AR), 3D printing and Artificial Intelligence (AI), teaching and learning must adapt to new delivery methods and approaches. With the advancements in IR4.0, it is widely discussed how universities must stay relevant, and the introduction of the Future Ready Curriculum (FRC) framework is targeted to develop future-proof graduates. From Education 1.0, 2.0, 3.0, and 4.0, where the use of technology has been gradually increased in teaching and learning, it is important to establish new digitilized teaching delivery methods, hence immersive learning is introduced as one of the sub-elements in FRC under transformative delivery. Virtual “immersive learning” such as Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR) are example of immersive learning approaches, and leverage immersive technologies and techniques to create an environment where learners feel fully immersed in the subject matter, providing both the context and experience. This review paper covers the recent trends and challenges in employing virtual immersive learning for engineering education.

Keywords: Augmented reality; engineering education; immersive learning; virtual reality

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Abstrak

Proses Pengajaran dan Pembelajaran (PdP) menghadapi cabaran baru pada abad kedua puluh satu dan ini memerlukan adaptasi bagi memastikan ianya memenuhi keperluan semasa. Dengan kemajuan teknologi-teknologi dalam Revolusi Industri 4.0 (IR4.0), seperti Reality Terimbuh, percetakan 3D and kecerdasan buatan, pendekatan dan kaedah PdP perlu disuaikan dengan perkembangan teknologi dan peredaran zaman. Kerangka Kurikulum Tersedia (FRC) dibangunkan untuk memastikan graduan universiti yang dihasilkan sentiasa memenuhi keperluan industri semasa. Dari Pendidikan 1.0, 2.0, 3.0 dan 4.0, di mana penggunaan teknologi telah ditingkatkan secara beransur-ansur dalam pengajaran dan pembelajaran, adalah penting untuk memastikan kaedah penyampaian PdP sentiasa relevan, justeru pembelajaran imersif diperkenalkan sebagai salah satu sub-elemen dalam FRC di bawah penyampaian transformatif. "Pembelajaran mendalam" maya seperti Realiti Maya (VR), Realiti terimbuh (AR), Realiti Campuran (MR) memanfaatkan teknologi terkini untuk mewujudkan persekitaran pelajaran yang lebih berkesan. Kertas ulasan ini merangkumi trend terkini pembelajaran imersif maya untuk pendidikan kejuruteraan.

Kata kunci: Realiti terimbuh; pendidikan kejuruteraan; pembelajaran imersif; realiti maya

1.0 INTRODUCTION

Future Ready Curriculum (FRC) was introduced to ensure teaching and learning in higher education stays relevant in the era of Industrial Revolution 4.0. In the FRC framework, there are three elements, which are organic and fluid curriculum structure, transformative learning and teaching delivery, and alternative assessment, as shown in Figure 1. FRC is constructed to prepare graduates to meet the challenges of the twenty-first century (Mokhtar & Noordin, 2019). The curriculum structure needs to be fluid and organic, and not rigid and fixed. This enables curriculum programs to be adapted to the current situation and meet the requirements of future employees and technological advancements. Transformative learning and teaching delivery creates futuristic learning spaces and the use of 4th industrial revolution that creates meaningful immersive learning experiences. Figure 1 shows the three main elements in the FRC.

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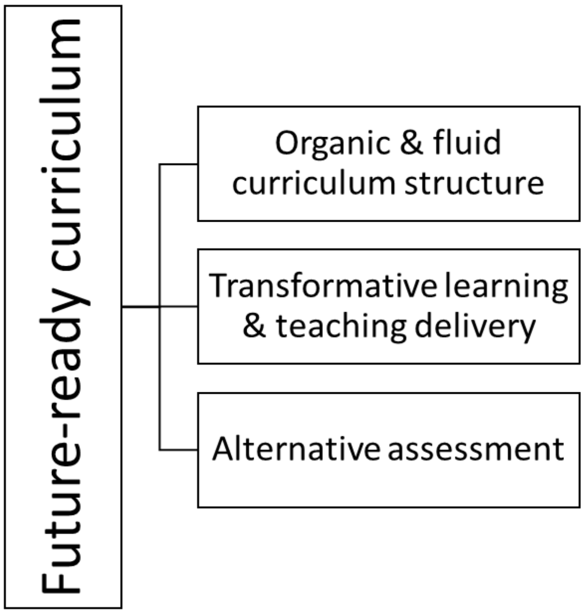

Figure 1. Future Ready Curriculum framework to meet twenty-first century requirements

IR4.0 does not only affect industries and manufacturing, but it is also a social revolution, affecting many parts of our daily life, including teaching and learning. For example, previously, in Education 1.0, university campuses and teaching and learning are limited to classrooms, in Education 2.0, teaching and learning is available online, and with the smartphone revolution, in Education 3.0, mobile and online learning has become more common. Now, in Education 4.0, with greater advancements in technology, AR and VR are used to improve teaching delivery methods.

Institutions of Higher Learning (IHL) need to ensure that academic programmes offered are able to produce competent and holistic graduates (values-based society) that can fulfil the manpower requirements of the country and industry. The world is now more connected, with borderless education. FRC is a flexible and organic educational model that can produce adaptable and future-proof graduates to address the 21st century challenges. Immersive learning is a sub-element of transformative learning and teaching, under FRC. Many review papers have covered the usage, trends, and challenges of Immersive Learning in many areas. However, there is a lack of review covering the recent use of immersive learning, specifically in the engineering field. This paper attempts to cover the recent trends of immersive learning in engineering from the year 2018 until 2023.

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2.0 IMMERSIVE LEARNING: VIRTUAL REALITY, AUGMENTED REALITY AND MIXED REALITY

In ancient times, humans learnt through their experience, practising, and by trial and error (Mystakidis & Lympouridis, 2023). This concept of experiential learning in a natural context is essential to developing true learners in a subject matter and is what experts call “immersive learning”. Traditional classrooms paved the way for high-scalability education for knowledge transfer to a large group of people, but lacked the important features of Immersive Learning. The modern invention of books and the eventual way of learning through the classroom changed learning scalability and enabled people to learn on a larger scale. This is, however, not without a drawback. People could acquire knowledge more quickly, but it also meant that they were separated from the context as well as learning from feedback and experience. Our current education system is more about what one knows and less about what one can do. This lack of context and experience of “immersive learning” in an actual live 3D environment is missing in our high-scale education system, especially in e-learning. The recent trend of e-learning (Azman et al. 2022) further increases the scalability of the transfer of knowledge but further reduces the experiential and contextual learning needed to build skills and proper understanding (Liubchak, Zuban & Artyukhov, 2022).

In past decades, virtual “immersive learning” has been introduced to address this concern, as shown in the FRC framework in Figure 2. It leverages immersive technologies and techniques to create an environment where learners feel fully immersed in the subject matter, providing context and experience. This includes Virtual Reality (VR), Augmented Reality (AR), Mixed Reality (MR), Simulations, Gamifications, and 360 videos. The goal of Immersive Learning is to enhance the overall learning experience and improve retention so the student develops a deeper understanding of the material.

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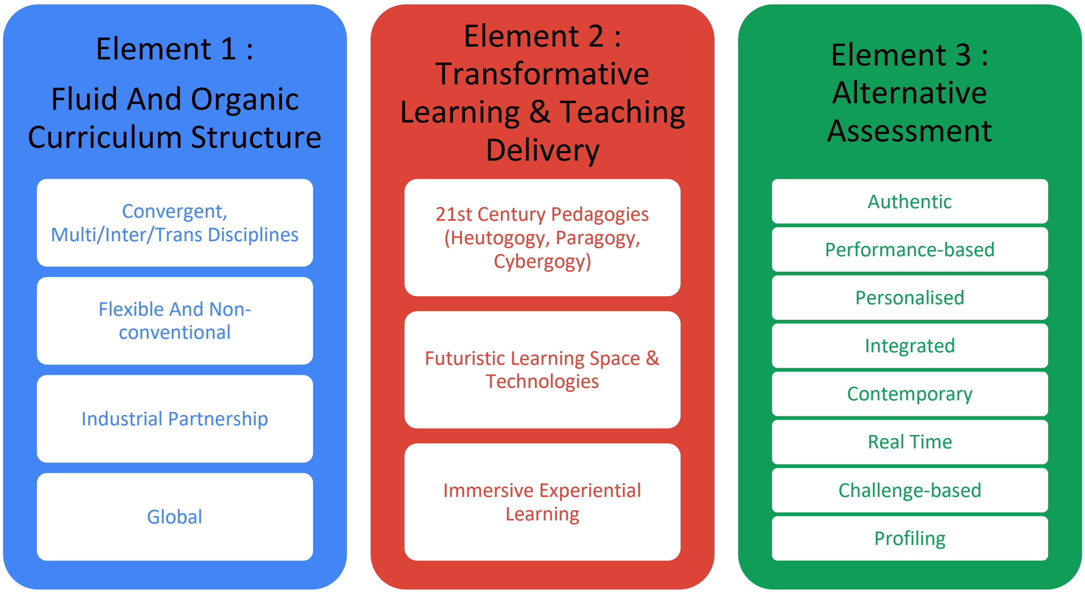

Figure 2. Immersive learning as a sub-element in transformative learning and teaching delivery

In some cases, virtual practice has been shown to be as effective as real-life practice (Iosa et al., 2012). This opens a lot of possibilities and opportunities in designing training and learning. Multiple studies have demonstrated that immersive media, such as virtual and augmented realities, can effectively boost learning across various application domains. These domains include STEM Education (Pellas, Dengel & Christopoulos, 2020), Language Education (Peixoto et al. 2021), History and Cultural Heritage Education (Challenor & Ma, 2019), Computer Science Education (Pirker et al. 2020), Medicine (Izard et al. 2018; Li et al. 2017), Construction (Wang et al. 2018) and other diverse application areas (Liubchak, Zuban & Artyukhov, 2022; Meccawy, 2022).

Figure 3 shows the increasing number of articles of immersive learning in the engineering field using the keywords: ("immersive" or "virtual" or "augmented" or mixed") and ("Learning" or "Education") and "Engineering"). The majority of articles are mostly related to virtual-reality (VR) and augmented reality (AR) as seen in Figure 4.

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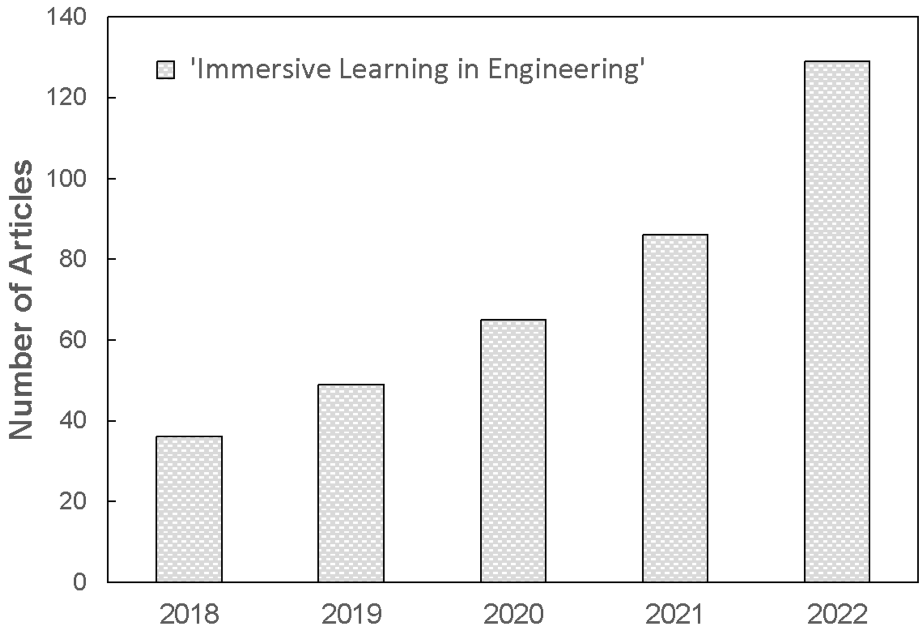

Figure 3. Number of articles searched on the Scopus database from 2018-2022

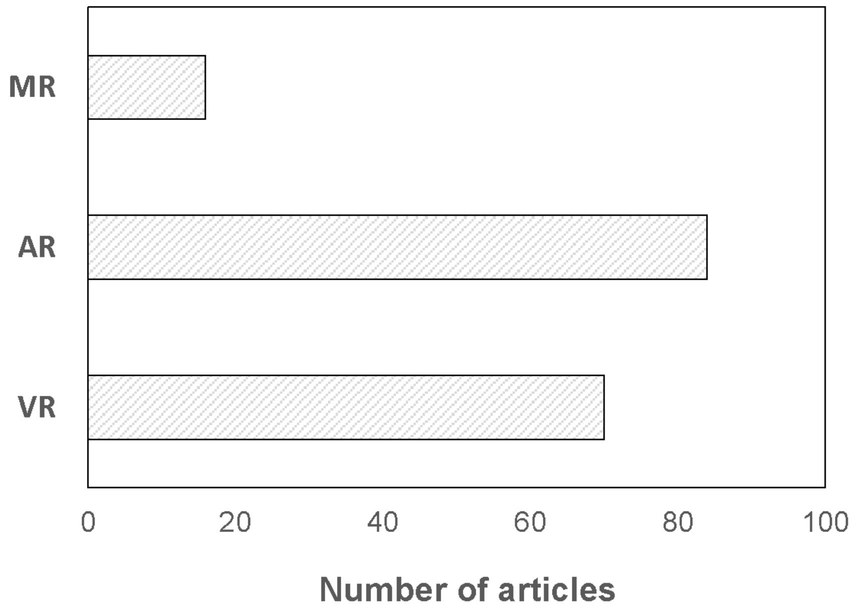

Figure 4. Number of articles searched on the Scopus database from 2018-2022

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3.0 RECENT TRENDS AND CHALLENGES OF VIRTUAL IMMERSIVE LEARNING IN ENGINEERING EDUCATION

Virtual immersive learning has been increasingly used in the engineering field as shown in Figure 5. Recently, a mobile application for milling machine visualisation based on augmented reality was developed to aid students as an early exposure of using the machine before the actual learning (Samala & Amanda, 2023). Such application can help students learn CNC programming and machining practices, reducing the cost of cutting tools and materials.

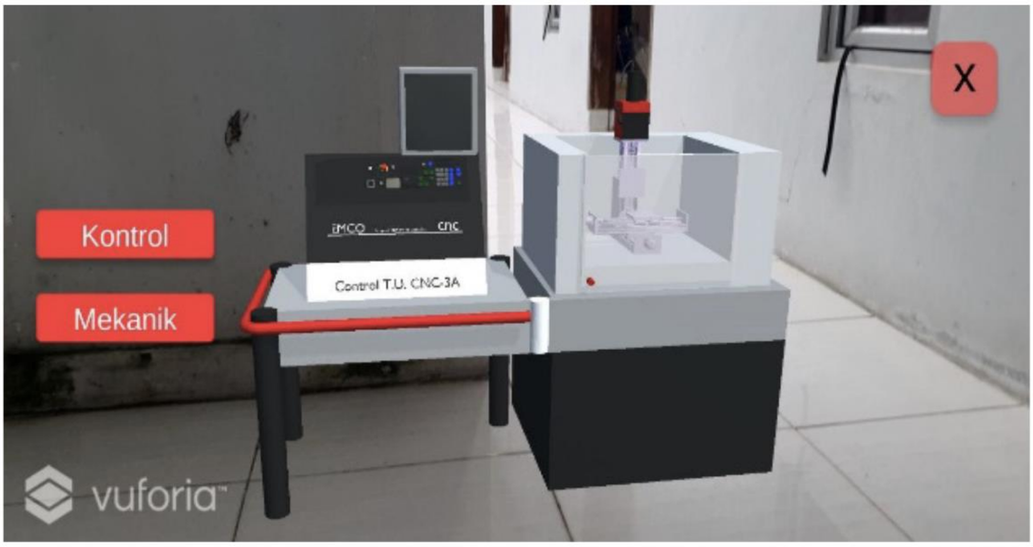

Figure 5. Mobile application using augmented reality (AR) for CNC milling machine practise (Reproduced under the terms of CC BY-NC 4.0)

In a different study, immersive VR videos showing laboratory components, part of a Biomolecular Engineering course, provided students with an engaging and appropriate learning experience (Wilkerson et al. 2022). To test the effectiveness of the VR videos, Figure 6, as a remote education tool, a survey showed that students mostly believed the videos provided the opportunity to work at their own pace and were an appropriate length. Almost half believe the VR videos were an acceptable alternative to in-person labs. However, two-thirds of students reported feeling discomfort while viewing the VR videos, highlighting one of the areas of concern using VR technologies.

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Figure 6. The Insta360 EVO VR camera in 180° 3D mode and the Google Cardboard headset used for VR videos of the laboratory component of a Biomolecular Engineering course. (Reproduced under the terms of CC BY-NC 4.0)

Del Alamo et al. (2020) have developed an online platform called FLUID-LABVIR, which offers an immersive experience for students in engineering and fluid mechanics subject. Based on audio-visual material and an immersive installation simulator, the platform provides students with a multi-platform web format for practicing laboratory experiments. The platform includes theoretical basics, measurements, images, animations, and explanatory videos. The virtual laboratory activity was conducted during the 2020/21 academic year, using three practices: Head Loss in Pipes (FM-HLP), Flow in Open Channel (FM-OC), and Wind Tunnel (FM-WT). Students found the simulator more appealing than traditional methods and a good substitute for in-person experiments.

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In another study, Pletz and Zinn (2020) undertook a structural evaluation of an immersive virtual learning environment for operator training in mechanical and plant engineering. A total of 13 individuals participated in the study by answering quantitative questionnaires and were asked to apply what they had learned virtually to the actual machine. Video recordings were made of both the virtual training and testing phases conducted on the physical equipment. A systematic qualitative analysis of video data was undertaken to discover errors, challenges, and other irregularities encountered during the application of the actual machine to generate additional possibilities for revision. The study employs video data for the first time to derive optimization potentials and to examine the learning transfer of action knowledge through virtual learning to real-world activities.

Grodotzki, Müller and Tekkaya (2023) developed a universal Augmented Reality platform for manufacturing engineering and education fields to display models, processes, animations, and simulations (Grodotzki, Müller & Tekkaya, 2023), as shown in Figure 7. The application platform allows instructors to manage online courses, teaching units, and study programs. It runs on iOS and Android systems, displays objects and additional information uploaded by instructors. A novel storage format reduces model storage size, improving phone performance. Common 3D file formats, FEM software results, and results formatted for analysis can be imported and converted. The platform and app are designed for easy-to-use setup by educators and intuitive use by students. Users can understand the individual parts that make up complex forming tools without carrying the weight.

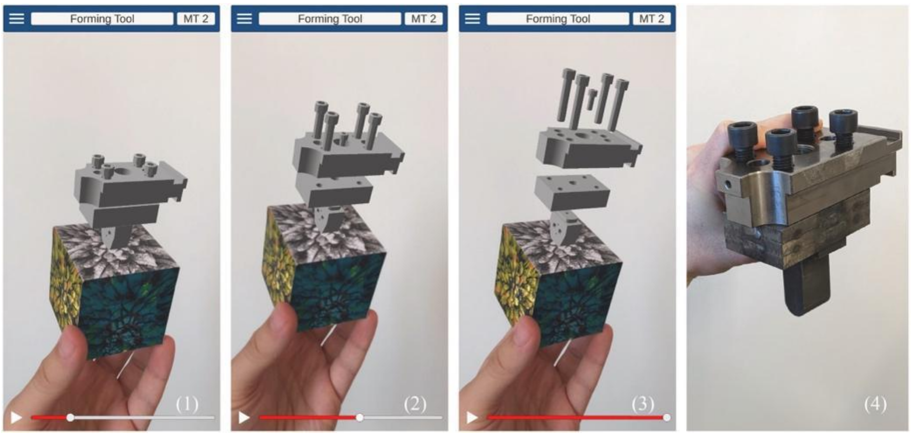

Figure 7. The animated sequence (visualizes the exploded assembly view of the upper part of a forming tool for die-bending operations using the AR mode. (Reproduced under the terms of CC BY-NC 4.0)

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A study conducted by Halabi (2020) demonstrated that VR and 3D prototyping promote effective communication, increase problem-solving skills, and enhance learning outcomes within the framework of project-based learning (PBL). In the study, VR is used together with PBL in a self-directed approach to design and implement a product using 3D software while using a virtual reality immersive CAVE display to evaluate their design. Based on the study's results, it was observed that the use of VR substantially impacted the distribution of cumulative project grades. The student projects' grades showed improvement with a notable enhancement observed in the implementation component. The virtual reality (VR) technique demonstrated enhanced communication and problem-solving skills compared to the traditional approach.

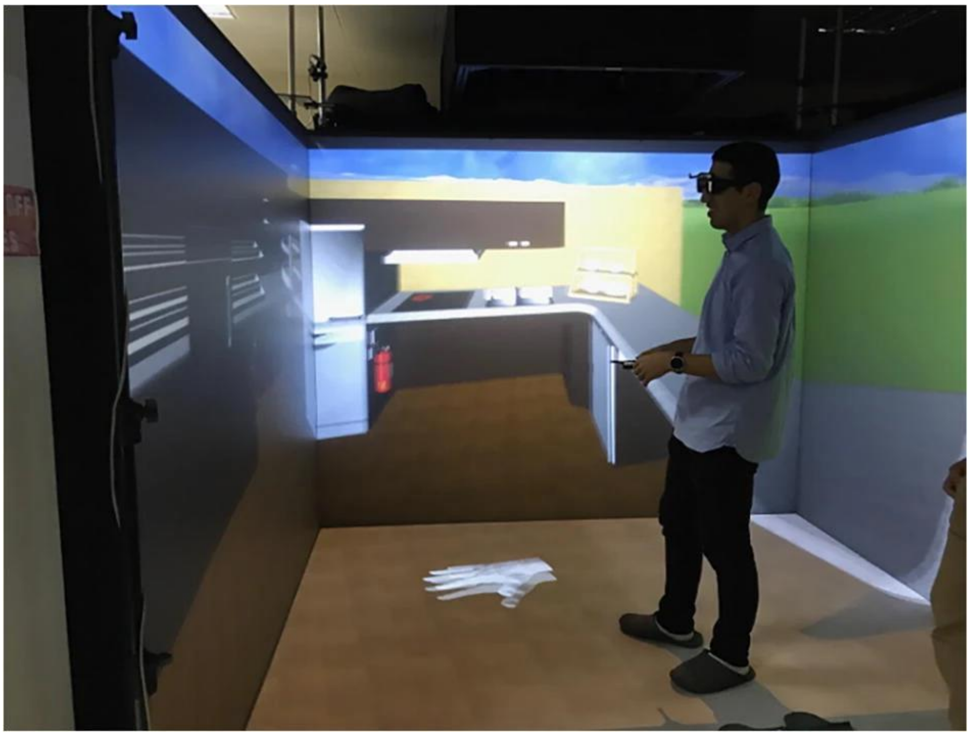

Figure 8. A student is seen to demonstrate the final design in accordance with CAVE (Reproduced under the terms of CC BY-NC 4.0)

A study by Schnieder, Williams and Ghosh (2022) compares the effectiveness of in-person and virtual engineering laboratory sessions. The virtual lab combined inquiry-based learning and gamification principles, creating a blended learning environment. Student feedback, engagement, and academic performance were assessed. Students reported greater confidence in the virtual lab than in in-person sessions, highlighting the benefits of

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interactivity and the ability to complete the lab anytime, anywhere. Figure 9 shows the confidence level of understanding the theory after completing virtual lab sessions. Students who completed all virtual lab experiments had higher class test scores.

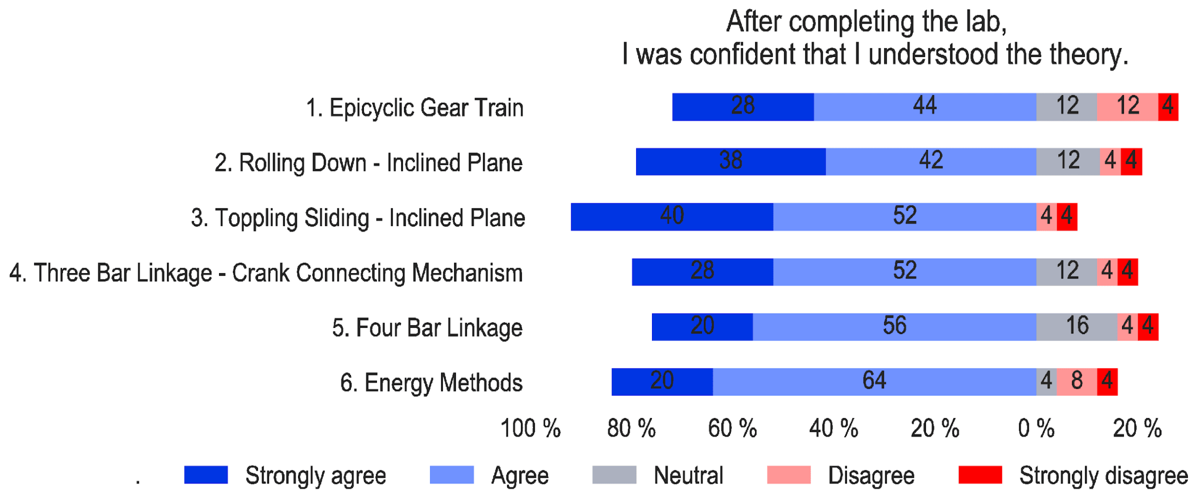

Figure 9. Confidence of understanding the theory of the virtual lab (values in percent). (Reproduced under the terms of CC BY-NC 4.0)

In manufacturing engineering, advanced product manufacturing approaches have become increasingly popular, necessitating the development of modern techniques to familiarize future workers with the latest manufacturing procedures. Salah et al. (2019) introduced a technique for using virtual reality in product manufacturing for students to be able to reconfigurable a manufacturing system (RMS), a complex topic often difficult for novices. Figure 10 shows a student learning in a VR environment. The VR teaching approach, which focuses on advanced manufacturing concepts like Industry 4.0 RMS paradigm, has been found to be effective and outperform traditional methods in terms of user understanding, satisfaction, errors, and completion time. The authors concluded that VR-based teaching methods are competent and efficient for future engineering education in Industry 4.0.

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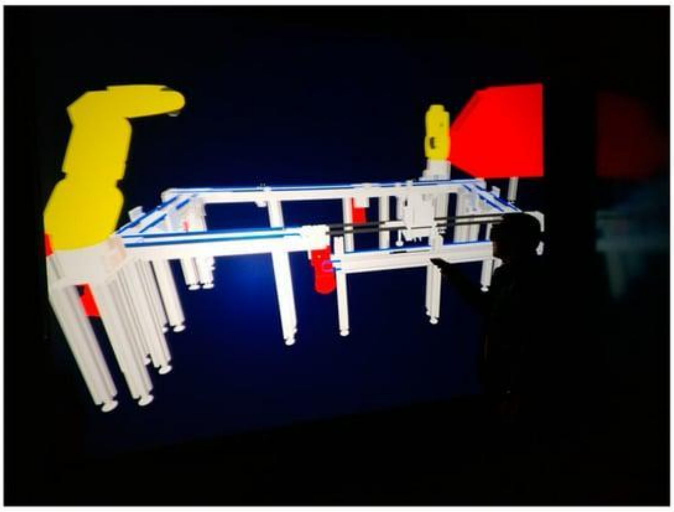

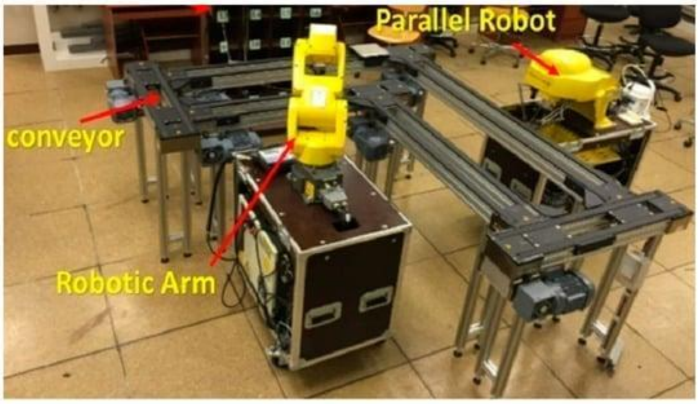

Figure 10. Student learning in the VR environment and an actual RMS system in shop floor. (Reproduced under the terms of CC BY-NC 4.0)

4.0 CONCLUSIONS

In conclusion, Future Ready Curriculum is a flexible and organic educational model that can produce adaptable and future-proof graduates to address the 21st century challenges. Immersive learning, with the aid of technology, is an important element in the FRC framework. Three of the conclusions drawn from this review paper on immersive learning in the field on engineering education are :

- Virtual Immersive Learning has proven to help improve student's grades as well as enhancing their problem-solving skills.
- Comfort is a sticking point in using virtual immersive learning, as some students have indicated their irritability in wearing a virtual head device.
- Students have approved using virtual Immersive Learning as a tool to complement (but not replace) conventional learning experience.

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Virtual Immersive learning is proving to complement and enhance the current educational system. This opens a lot of opportunities to revolutionizing education itself in the future.

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