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Author(s): Shamsuzzoha, Ahm; Al-Kindi, Mahmood; Kankaanpaa, Timo

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Implementation of virtual reality in technical education – an innovative view

Ahm Shamsuzzoha[1]*, Mahmood Al-Kindi[2] and Timo Kankaanpaa[3]

[1]University of Vaasa
School of Technology and Innovations,
Wolffintie 34, 65200 Vaasa, Finland
E-mail: ahsh@uva.fi
*Corresponding author

[2]Sultan Qaboos University
Department of Mechanical and Industrial Engineering
P.O. Box 123, P.C. 33, Muscat, Oman
E-mail: kindim@squ.edu.om

[3]Vaasa University of Applied Sciences
Department of Information Technology
Wolffintie 30, 65200 Vaasa, Finland
E-mail: timo.kankaanpaa@vamk.fi

ABSTRACT

Advancement of virtual reality (VR) is creating many opportunities to efficiently managing educational system in the present days. The application of VR in educational sector can contribute towards to cope up with today's digitalized educational management system. To keep such objective in mind, this research study investigated the possibility to apply VR in education, especially in technical education and analyzed its potential outcomes. The inherent benefits of VR in technical education are elaborated within the scope of this research study with the aim to meet the expectation of today's up-to-date student generation. A case study on the application of VR is conducted to demonstrate how the innovative technology can be employed to produce creative training and learning engineering curriculum. Overall outcomes from this case example are presented along with the various works done by the researchers and practitioners on virtual reality are reviewed and highlighted as well.

Keywords: Virtual reality, 3D visualization, management of education, technical education, innovation, case study.

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Biographical notes:

Ahm Shamsuzzoha has been working as a University Lecturer (ICT), School of Technology and Innovations, University of Vaasa, Finland. He received his PhD in Industrial Management (Department of Production) from the University of Vaasa, Finland and his Master of Science (Department of Mechanical Engineering) degree from the University of Strathclyde, Glasgow, UK. His major research and teaching interest lies in the area of supply chain management, enterprise collaborative networks, project management, product customization, and simulation modelling. He has published several research papers in both reputed international journals and conferences.

Mahmood Al-Kindi is working as an Assistant Professor at Department of Mechanical and Industrial Engineering, Sultan Qaboos University, Muscat, Sultanate of Oman. He received his PhD from Illinois at Urbana Champaign, USA in 2010. He received his Master of Science degree from the Louisiana State University, USA in 2003. His research interests lies in the area of Quality and Six Sigma, Innovation and Business Entrepreneurship, Lean Manufacturing, Production Planning and Control. He has published several research papers in both international journals and conference proceedings.

Timo Kankaanpaa working as a Principal Lecturer, Department of Information Technology, Vaasa University of Applied Sciences. He received his Licentiate of Science (Economics and Business Administration) degree from University of Vaasa. His research is mainly focused on software development and application, collaborative enterprises and energy technology. He has published several research papers in both reputed international journals and conferences.

1. Introduction

In order to manage existing educational system efficiently and to ensure effective teaching and learning environment, it is necessary for the educational institutions to mix both theoretical and practical knowledge to the learners. The theoretical knowledge can be delivered to the learners by reading books or articles but it is critical to achieve practical experience of the studied topics in order to enhance the students' skills. It is however, still difficult for the students to apply their knowledge towards the practical situations (Häfner et al., 2013). Technical education is no exception to the problem of the gap between theory and practice. In general, engineering curriculum has been designed to provide a basis of engineering science followed by practical experience in a number of engineering specialties. Several recent innovative researches in engineering curricula have focused on the need to integrate practice and theory (Sampaio et al., 2010; Abdulrub et al., 2011; Abulrub et al., 2011; Penland et al., 2019). In such consequences, adapting an up-to-date technology and tool such as VR technology can be a useful aid to ensure practical knowledge to the engineering students through an immersive 3D visualization.

The research on virtual reality in conceptual learning is growing rapidly due to its accompanied benefits. The interactive and immersive 3D visualization technology is promising for the engineering education management and training (Abdulrub et al. (2011). Increased level of maturity towards VR technologies triggers to expand research from the military and visualization realm to other domains such as education, art and psychology. Although, VR is extensively used in military and games industries but its application in education sector is relatively young. In general, VR can have strong motivational power through immersion environment (Gallagher and Cates, 2004; Corbetta et al., 2015). There are several educational VR projects have been created, which offer VR-based learning applications (Fowler, 2015; Hubbard et al. 2017; Kizilkaya et al. 2019). From research study, it is shown that most of the VR projects involve the creativity, exploration and collaboration between both remote and collocated learners. This technology represents a tool, which can create a bridge for cooperation between industries and next generation engineering students with necessary skills and expertise required for business success (Gorski et al. 2019).

The development in the field of VR is adequate so far and can be considered in innovative applications such as education, training and research in higher education (Abulrub et al., 2011). The application of VR in education offers both benefits and challenges. The main benefit of VR is that it enables to create a mimic environment of the real life environment, from where the learners achieved substantial knowledge of the real ones (Kizilkaya et al. 2019). Often it may be difficult and even inaccessible to the real environment, which can be comfortably created through virtual reality technology. From this virtual environment, the learners can get the experience of feeling of real ones by interacting within the environment surrounds them (Häfner, 2013).

There are several challenges to create and to implement VR environment in educational domain. The main challenge to apply VR technology in education sector is associated to its relatively higher implementation costs, which are associated to equipment, software, expert's people etc. Due to such limitations, it is often difficult and cannot afford by the educational institutions to establish virtual reality laboratories (Häfner, 2013, Gorki et al., 2019). However, recent advancement in VR technology has made it more feasible to implement such environment in future teaching strategies. In spite of the cost issue, the benefits of VR in education and learning arena are huge (Gorski et al., 2011).

Due to increasing level of demand for innovation in technical education and recent advancement in 3D visualization technology, wide range of engineering teaching and training can be supported by the VR environment (Grajewski et al., 2015). The VR technology can be used as a supportive methodology and tool for the advancement of technical education. It significantly enhances the learning experience through realism and interactivity. In order to apply VR approach in engineering education, care should be taken due to the descriptive and complex nature in engineering problems. The application of VR can bring new style in technical education through teaching technique, especially the use of laboratory demonstrations. Such demonstration is directly used to enhance the student's practical knowledge. Based on the above circumstances this research study summarizes following two motivating research questions:

(1) What are the associated benefits to apply VR in technical education?
(2) How VR can be used to support innovation in practical knowledge and learning for engineering students?

The rest of the paper is organized as follows: Section 2 demonstrates the relevant literature of VR applicable to various domains including management of education, while Section 3 highlights the research methodology adopted for this research study. Applications of VR in technical education sector are elaborated in Section 4. Essential technologies and tools to create VR working environment is outlined in Section 5. An elaborative case example is demonstrated in Section 6 to explain the learning process through VR. Generic discussions and limitations of VR in highlighted in Section 7, whereas Section 8 concluded the research outcomes with future research directions.

2. Literature review

2.1 Virtual reality: today's dilemma

Today's advancement of information and communication technology (ICT) has been transforming manufacturing industry in myriad ways. Many of the relevant ICT developments are not made directly for the sake of manufacturing, so industrial researchers and professionals may not be fully aware of the adaptation of the new technologies (Khalid et al., 2018). One critical area of ICT is VR that already applied commonly in various areas such as entertainment, design and manufacturing and simulation training (Häfner, 2013; Gorski et al., 2016). In reality, VR already has different applications within manufacturing sector (Pandilov et al., 2015). VR applications for the manufacturing sectors are applied extensively and its implications for the sector are significant. It is therefore, necessary for the manufacturing researchers and professionals to be prepare themselves to face the challenges and take benefits that VR offers.

The concept of virtual reality (VR) can be defined as a computer-generated environment, where the viewer can experience a different reality. This environment is often considered as an extension to 3D computer graphics, which offers a three-dimensional view. The integration of 3D design and manufacturing provides manufacturing firms a means of envision, refine and develop a product or process with substantial time and cost savings (Gorski et al., 2011). The VR environment offers a person a sense of reality. This technology allows the designers to virtually manufacturing and maintenance works (Grajewski et al., 2015). This technology mainly uses a combination of headsets, controllers and optics. Often the headsets are integrated with headphone to upgrade the user's experience with the aid of 3D audio system.

2.2 Applications of virtual reality in various domains

In literature, substantial research has been conducted on the application of VR in different domains starting from military sector to industrial and service sectors. It is widely used in military training (Zyda, 2005), automotive and aerospace design (De Sa and Zachmann, 1999), medical training (Gallagher and Cates, 2004; Corbetta et al., 2015; de Boer et al., 2017), and entertainment (Stapleton et al., 2002; Tromp, 2017; Jung et al., 2018). Automotive giant Jaguar Land Rover used 3D digital prototyping to make decisions in the early stages of design (Attridge et al., 2007). VR offers suitable environment for any kind of design reviews that supports to reduce product development lead-time and costs with improved quality of new products and services (De Sa and Zachmann, 1999).

The VR technology has made new opportunity for delivering education and training in immersive ways. Past challenges from technology and cost have impeded advancement of VR in education and training. Industries as well as educational institutes are now moving fast to adopt VR as a training tool (Grajewski et al., 2015). The efficient immersive environment created by VR applications has been very successful in developing positive learning outcomes in a variety of fields (Jayaram et al., 1997; Gavish et al., 2015; Fiard et al., 2014; Gibson and O'Rawe, 2018). The VR provides on-site training and learning in a safe and controlled environment (Berg and Vance, 2017. It supports virtual learning in impossible locations through the access to cost-prohibitive equipment (Jerald, 2017).

VR technique presents a new way to engage technical students in the learning process. It creates technologically minded students with higher levels of engagement in learning process than to traditional teaching methods (Dalgarno and Lee, 2010; Lawrie, 2017). Such explorative environment allows the users to experiment with an environment that in real world could be dangerous (Bricken, 1991; Blazy, 2015; Lawrie, 2017). Due to nonreality of the resources in this environment allows the users to conduct experiment which might be dangerous in the real world. Through this sound and safe learning environment, the users would be able to get experience and feeling as if real with minimum cost and hassles (Fowler, 2015; Hubbard et al., 2017). In addition, the costs associated with mistakes or errors in VR environment are lower in comparison to the potential physical costs in the real world.

The VR technology as training tool can be designed to have limited or no physical prototypes (Grajewski et al., 2015; Jerald, 2017). It is often possible to use a hybrid system, where both physical and virtual interfaces are combined, known as physical mock-ups of interfaces. VR training tools can be used with minimum supervision (Dalgarno and Lee, 2010; Hubbard et al., 2017). A user can be fully engaged in the virtual environment where he\she can acts as he\she do in the real world (Craig et al., 2009; Berg and Vance, 2017). A summary of few applications of VR in various domains are highlighted in Table 1. From Table 1, it is noticed that

Table 1. Applications of VR in various domains.

Serial number	*VR application areas*	*Contributed authors*
1	Product design and development	Craig et al. (2009); Gorski et al. (2011); Grajewski et al. (2015); Pandilov et al. (2015); Gorski et al. (2016); Berg and Vance (2017)

2	Medical science	Aggarwal et al. (2007); Bellani et al. (2011); Kandalaft et al. (2013); Fiard et al. (2014); Corbetta et al. (2015); Laver et al. (2015); de Boer et al. (2017)
3	Education	Bricken (1991); Dalgarno and Lee (2010); Blazy (2015); Fowler (2015); Nikolic et al. (2015); Hubbard et al. (2017); Lawrie (2017); Spolaor and Benitti (2017); Bower et al. (2017); Gorski et al. (2019); Kizilkaya et al. (2019)
4	Games and entertainment	Guttentag (2010); Tromp (2017); Jung et al. (2018); Moorhouse et al. (2018)
5	Manufacturing industry	Jayaram et al. (1997); Gavish et al. (2015); Grabowski and Jankowski (2015);
6	Business and entrepreneurship	Tromp (2017); Bonetti et al. (2018); Gibson and O'Rawe (2018)
7	Tourism industry	Huang et al. (2016); Castro et al. (2017); Jung and tom Dieck (2017); Jung et al. (2017); Gibson and O'Rawe (2018);

2.3 Applications of virtual reality in management of education

The application of VR can be a useful aid towards the management of education in a wider perspective. In educational development, it is necessary to offer unique opportunities to provide hands-on learning environment. Often, it can be difficult, costly and even impossible to get a hands-on experience of theoretical topics. Students in higher education demands to be well-prepared for their professional life and expect more courses with practical application of theoretical knowledge acquired during their studies. Moreover, students can be benefited greatly when having the possibility to improve their soft skills in addition to hard skills. The courses offered on virtual reality are worked on simulating interdisciplinary industrial projects and the aims are to developing skills such as methodical approach to practical engineering problems, teamworks, working in interdisciplinary groups and time management (Häfner et al., 2013).

Application of VR technology offers the ideal venue to allow 'practice' without risk. There are infinite number of realistic scenarios that can be presented using this technology. As an example, risky and life threatening working environment can be simulated on a real-like fully computerized mannequin (Gorski et al., 2019). This mimicking environment can be videotaped and viewed later for performance monitoring and analyzing. Viewing of such videotaped performances allow the learner's personal reflection on the effectiveness of the works as done virtually. This learning environment enabled learners to practice their skills and repeat the scenarios thereby gaining valuable insights into their overall performances for further improvements.

In addition to offer an opportunity of providing real-like practical experience through the VR technology, it reduces the risk of hazardous material in training and teaching environments and enhances the opportunity to explore inaccessible or restricted locations such as chemicals reactors. It protects costly environment by reducing the impact on climate through cutting the wasteful

material or eliminating harmful mistakes by learners. Moreover, VR technology helps to manage the learning of physically disabled learners. It enables special-need engineering students to experience an environment when it is difficult to do that otherwise. Furthermore, in case of today's ever increasing online or distance learning, VR technology may provide a platform for virtual lab to be utilized effectively in distance learning courses (Penland et al., 2019). This technology makes student-learning experience out of the ordinary methodology that helps in branding the educational institute.

3. Research methodology

This study was initiated with an extensive literature review investigating the application of virtual reality in technical education with respect to training and safety issues. From the literature survey, it was noticed that few research works have been done on technical education or management of education, although application of VR in other sectors are increasing rapidly due to its inherent benefits. Initial findings from the literature survey were motivated the development of a framework for applying VR for engineering training and safety education. Subsequently, virtual reality-based prototype scenarios were developed through portraying a welding operation and its relevant hazards. System trials and discussions were carried out with students, safety managers and educators in order to assess the prototype system's effectiveness and usability.

Furthermore, literature review showed that there are limited works conducted on the training and safety issues using VR technology in education, especially in technical education. Based on these analyses, the required educational contents including safety rules and safe work procedures were identified for the technical education system. Various common accident cases were collected and analyzed, confirming the need for improved hazard identification capabilities among operational personnel. In such consequences, welding operation is considered as one of the most vulnerable industrial case, where required occupational safety and health hazard need to be focused. Based on this objective, a prototype system on welding operation was then developed to integrate VR safety scenarios that would improve learners' safety knowledge and hazard recognition ability. The system was then implemented and evaluated through hands-on trials.

To conduct this study, final year undergraduate students from a Finnish applied university were selected. The students were selected from mechanical engineering discipline with some industrial experiences too. The students already have good theoretical knowledge on welding operations but very limited practical knowledge. Due to limited facilities and safety concerns, students were encouraged to have their practical experience on welding operation through VR environment, where they were experienced welding operations by mimicking the real-life situations. At the end of the VR-based experiments, students were interviewed to express their feelings or feedback on the virtual welding operations.

4. Application of VR in technical education

Due to the poor economic situation, the global industry and SMEs are facing a fierce competitive environment. Thus, educating the 21st century engineering students require accurate understanding of the current industry challenges. Current industries require engineers to have advanced problem-solving skills and apply theory to real world problems. There needs a strong collaboration between industry and academia in order to produce motivating engineers with the necessary skills. This form of collaboration also build on industrial engagement to benefit from its up-to-date technological advancement that can provide various innovative solutions and formulate

an educational system to train engineers with sufficient skills to be employable in today's competitive market environment (Le et al., 2015). Thus, engineering education system must need to be aligned with industries requirements (Reese and Eidson, 2006).

The explosive development of ICT and increasing interest motivates educational institutions to adopt sophisticated technological means, innovative environments and equipment (Dehn et al., 2018). Hence, today institutions are considering the use of interactive installations, simulation environments and virtual reality (Hubbard et al., 2017). Such specific interest to educational institutions in the use of VR displays and computer generated interactive experiences allows students to travel through space and time without stepping out of the real industrial establishments (Nikolic et al., 2015). In recent days, research on VR in education sector has focused on the potential of immersive displays, which makes the learning experience easier and more realistic (Padilha et al., 2018).

It is also important to mention how VR environment can be adapted effectively and efficiently as pedagogical tool in the industrial safety education. The accompanied advantages of VR can be applied in educational processes in various formats such as (Le et al., 2015):

- Safer practical learning, where the students can identify the potential risks or hazards by experiencing within virtual environment;
- Role-playing experience, where both the teachers and students can synchronously and asynchronously collaborate with each other to increase their practical knowledge within an immersive and collaborative VR environment;
- Reflective educational method, which supports students with the opportunities to use the virtual environment as safer working place;
- Authentic learning environment that provides students to examine the real-life industrial activities within virtual environment.

The VR is increasingly applying in educational industry due to its inherent benefits. It is highly usable in engineering education due to its 3D visualization technology (Manuel, 2017). This 3D visualization technology supports engineering graduates with necessary knowledge to add value, reduce time-to-market and reduce cost. It enables graduates to understand how to define business requirements and reducing risk of lost profits and/or making products that do not meet customer expectations (Le et al., 2015). It is therefore required for the educational institutions to make necessary planning for the implementation of VR learning environment with respect to infrastructure development and policymaking (Al-Zoubi et al., 2007; Lamb et al., 2010). In order to manage current educational system, there needs distinctive skills to support innovative teaching and learning. To stay in competition, engineering students needs to prepare themselves to experience to both theoretical as well as practical knowledge towards the real industrial problems.

It can be worthwhile to mention that although VR environment cannot compensate fully the real life experience but it can provide substantial level of understanding of the real system through mimicking. In the academic courses, there must be balanced between the practical experiments to the virtual experiments. The teachers should carefully design courses to divide them into practical versus virtual experiments that mainly depend on the nature of the courses and market demands. Teachers should decide which experiments could be conducted using VR environment and which are not. Of course, the nature and type of the experiments are fully dependent on the available resources too. Priority should be given during the selection process of the experiments. For instance, mainly risky and dangerous experiments that concerns with high level of safety for the students should be conducted by using the VR environment if possible.

5. Creation of VR operational environment: essential technologies and tools

In order to create three-dimensional VR operational environment there needs to integrate several technologies and tools. Most of the techniques and tools are compatible with each other, which is necessary to develop a seamless VR working environment. This VR environment combines both hardware and software, which allow the designer to be immersed in the environment. The designer should have should have the explicit technical knowledge both on the real life experience as well as virtual reality environment. Such tacit knowledge helps the designer to select the input/out devices required to create an efficient virtual environment. The VR operational environment can be defined as a system that is implemented to address a specific technical scenario representative of actual issues facing an industrial facility. This system provides the operational engineer with high quality, stereoscopic graphics by using a head-mounted display, which is act as an input/output device to interact within the virtual environment.

Required movement of the head-mounted display is monitored and controlled by electromagnetic positioning devices that automatically allow the user to look around. Different movements of the head are monitored and tracked by the hands of the user by additional positing devices. These movements are used to create and manipulate operational scenarios in the virtual environment. In order to monitor the movement of the fingers and wrist, the user uses an instrumented glove. The operational personnel use such virtual working environment to select optimal operational sequencing, evaluate required tolerances, create operational plans and results visualization.

In order to design and develop VR environment it is essential to integrate multiple domains and synchronize with related technologies. Such integration makes the VR application more effective and efficient in nature. The VR environment allows the technician to pursue operational activities virtually. This virtual operational system supports relevant training instruction with a reliable and easy way. This environment provides real-time simulation and interaction with a virtual 3D world.

The application of VR environment requires technologies such as Unreal Engine 4, HTC Vive, HTC Vive Headset, HTC Vive Controllers, HTC Vive Base station, Vive Tracker, etc., (Vive, 2017). The Unreal Engine 4 is used as the main software to create the virtual environment. This environment is required to simulate virtual industrial operations. The HTC Vive is a virtual reality headset that is designed and developed by HTC and Valve Corporation. It offers ‘room scale’ tracking technology that supports the user to move in 3D virtual space. The HTC Vive consists of one VR headset, two controllers and lighthouse base stations (Fig. 1), which are required parts to create and operate VR environment.

Fig. 1. HTC Vive bundle essential parts.

The HTC Vive headset tracks the head position through a gyro sensor, an accelerometer and a laser position sensor. It uses two screens, one per eye and includes a front-facing camera that allows the user to observe their surroundings. The HTC Vive controllers are considered as the hands of VR that let the user wirelessly interact with virtual objects, making a more immersive experience for the user. It consists of a track pad, grip buttons and a dual-stage trigger as seen in Fig. 2. (Ben, 2017). The Vive tracker functions similar to Vive controllers and the Vive headset by collecting information from the infrared emitted by base stations. By using the tracker, the user will have an immersive VR experience (VRHeads, 2017).

Fig. 2. HTC Vive controller buttons.

The HTC Vive base stations, also known as lighthouse-tracking system consists of two black boxes that create a 360-degree virtual space up to 15 x 15 foot radius (Vive, 2017). This lighthouse tracking system tracks every moment with sub-millimeter precision with the aid of 37 sensors in the headset (Ben, 2017). Fig. 3 displays a HTC Vive base stations set up position.

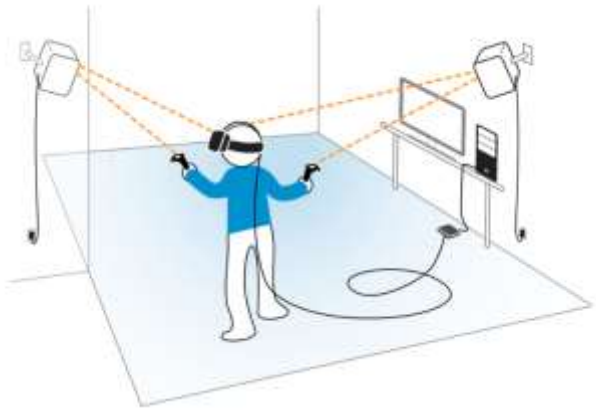

Fig. 3. HTC Vive base stations set up position.

6. Learning through VR: a case example

This case example was considered following the practical work in the welding laboratory in a technical university. It was basically a spot welding operation conducted on a sheet metal by a group of selected students. The students were then invited to take part with the virtual operation considering the same spot welding. In order to demonstrate the application of VR in technical education, this spot welding on a sheet metal was conducted in a virtual reality environment. The

welding operation was performed through a robotic arm, meaning that the virtual robot was used in this process. This VR work environment was developed with the help from ABB Robotstudio software (http://new.abb.com/products/robotics/robotstudio). In order to conduct such experimental set up required robot is selected along with spot welding tool attached at the robot's arm. The initial set up for spot welding using robot is displayed in Fig. 4. From Fig. 4, it is seen that welding tool is positioned on the job sheet for necessary welding operation. Different types of welding tools can be attached on the robot arm depending on the welding requirement.

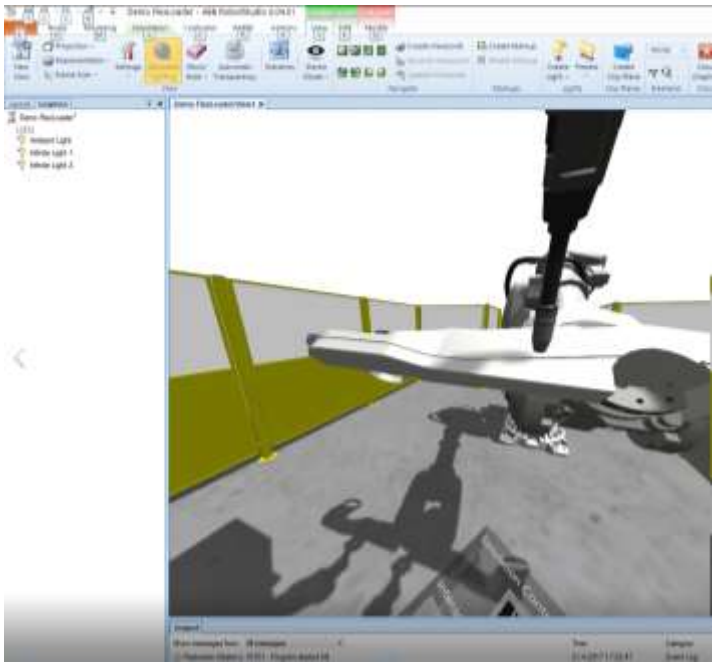

Fig. 4. Display of spot welding through VR environment.

The VR welding environment was created through Visual Components software (http://www.visualcomponents.com/). Required 3D working environment is created by this software application successfully. In order to move to the necessary position to perform the welding operation, the operator uses teleporting. Such teleporting enables the operator for longer movements by walking. The operator uses VR glasses to visualize the movement of robot arm. The glasses cover the all the essential views of visions. Two HTC VIVE lighthouses (https://en.wikipedia.org/wiki/HTC_Vive) are used to view and control the robot arm for necessary welding operations. The user uses front-facing camera as attached to the headset to monitor surroundings areas.

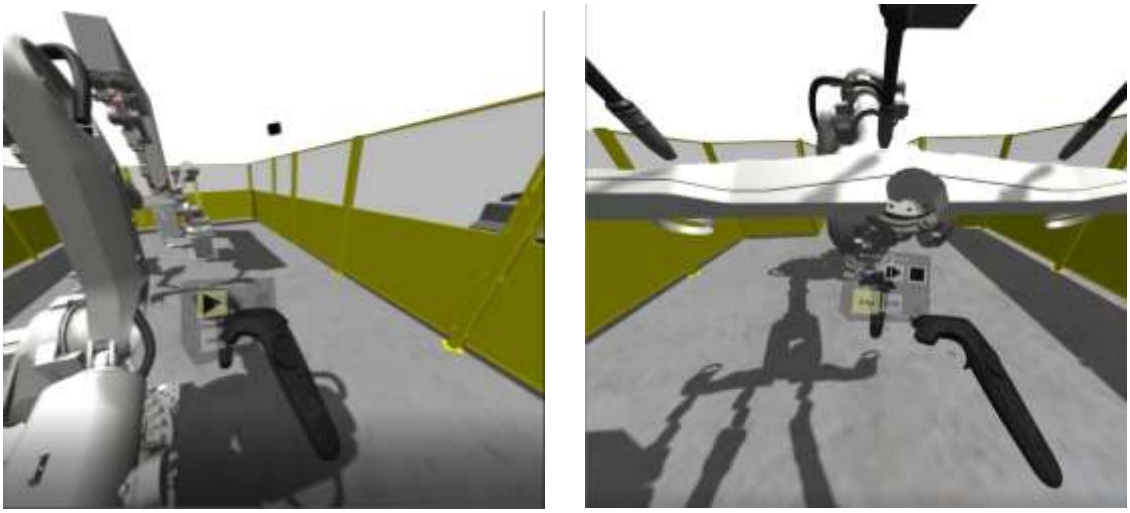

Fig. 5. Display of HTC VIVE controller as used to spot welding through VR environment.

Fig. 5 displays the HTC VIVE controller that controls the operator's movements to weld specific area on the sheet metal. Through such teleporting device, the operator enables to position him/herself accordingly. The HTC VIVE controller have several commands such as jog, play, edit, delete, etc. These commands are required for controlling the robot's arm, which are necessary to perform specific operation efficiently.

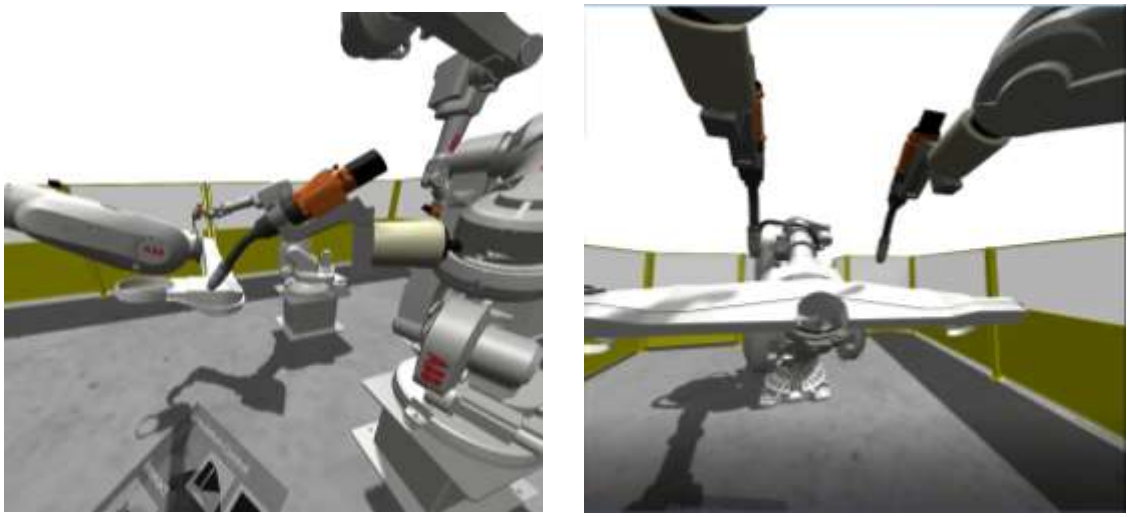

Fig. 6. Display of two-robotic arms used for spot welding through VR environment.

The teleporting is also used for operating multiple welding tools as attached the robots arms. Fig. 6 displays the two welding torches as attached to the two robot arms. Through simulation control exact positioning of the spot welding is dine, which is displayed in Fig. 7 accordingly.

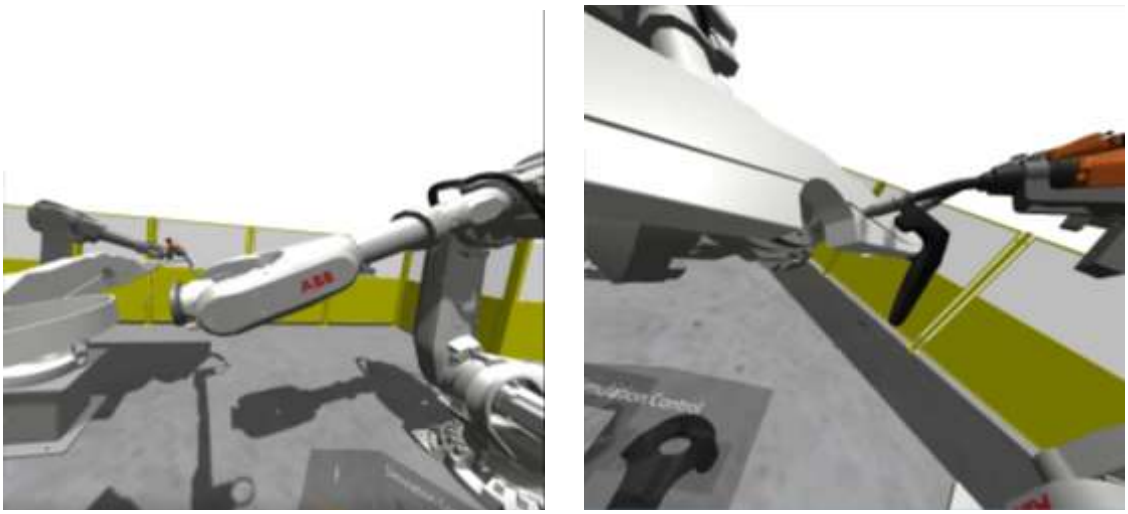

Fig. 7. Display of spot welding through VR environment.

The required twisting of the welding tool is controlled by the command ‘jog’, which grab the robot arm and twist it according to the operational needs. Fig. 7 displays the twisting position of the robot arm as necessary to spot different locations of the sheet metal. Other available commands are also used to spot welding for better performance.

7. Discussions and limitations of VR in engineering education

VR is helpful to teach technical students through an effective way of emphasizing things through visualizations, which is not possible by the traditional teaching methods. It offers amazing experiences that may never be possible in the real world of learning. It motivates students to learn with the use of this technology while they sit and watch something instead of reading it. In today’s classroom environment, it is often difficult to create a productive engagement within the class. With the help of VR technology such challenging environment can be disappeared, where students will feel tempted to talk about their experiences within their virtual world. It also removes the language barrier which often appears a big problem to education.

Teaching through VR environment helps students to engage more as compared to traditional school based learning. In traditional schooling, learning is mainly based on theoretical approach due to the lack of resources such as cost of laboratory equipment, trainer, maintenance and upkeep etc. In addition, for students it is often a difficult task to access a real-life industrial establishment due to limitations such as getting the permissions, security concern, available time of the personnel, etc. Moreover, some operational activities in industries are very risky, dangerous and cumbersome for the students to access and get a practical experience. Considering such limitations, it is quite easy and recommended to learning through VR technology. Research shows that application of VR has positive benefits for learning in compare to traditional teaching (Huang and Liaw, 2011; Wang et al., 2016; Delello et al., 2018; Lan et al., 2018).

This VR technology is especially helpful for the technical or engineering students to learn technical works virtually in an easy, cost effective and safer way. If the students cannot experienced with real life examples then the VR technology can be a good solution. Through the application of this technology, students would be able to get very similar experience, as this is just the replications of the real ones. There are many learning benefits offered by the virtual world.

One of the major appealing features of VR technology to engineering students is the ability to offer experience of places that are otherwise inaccessible. For instance, deep-water welding (in the petroleum industry) could be something impossible to accomplish with the students in engineering, but viable to perform via virtual reality. Some parameters that cannot be realized in reality could be tested in the simulation environment by increasing learning. A nuclear reactor or boiler can be an example, where VR can be applicable to inspect and work safely in a virtual environment.

In this immersive environment, the teachers have to plan carefully to their courses in order to engage students in virtual world without much hassle. The course contents need to be tailored according to virtual world as well. The implementation of VR in technical education is not an easy job. It has several limitations. The basic limitations are associated to the cost and time. With respect to cost, it can be noted that to create such VR environment there needs substantial amount of money to invest to buy the equipment. In addition, it is also necessary to hire experts with knowledge in programming and software, which are critical to execute the VR environment successfully. In addition to cost, implementation to this technology requires time. After buying the required equipment to create VR laboratory, it is necessary to train the technician/operator efficiently to create and operate within the VR environment. Before starting teaching the students, the teachers also need to explain the procedural steps to create VR environment from an existing systems or operations.

This technology therefore requires educational training, operational learning and to know proper usability, etc. The application of VR-based welding operation as explained within the scope of this study results better learning with respect to testing various parameters and/or changes the conditions of welding. For instance, it is always difficult and costly to do welding operations by changing the temperature, welding rods, flux, etc. Whereas, similar operational environment can be mimics by the VR environment easily from where students can learnt the fundamentals of welding. From this study, the authors compared the manual welding results to the VR-based welding results and the outputs were very close, which shows the superiority of VR technology. It can be worthy to mention that VR technology may not be used in each class of specific course but only can be applied to experiment to critical operations that need to focus more than others do.

8. Conclusions and future works

In today's competitive business environment, companies need students, especially technical students with distinctive knowledge and skills, to implement cost-effective innovative solutions. Such solutions provide companies to improve profit margins, differentiate their brands, reduce cost with guarantee on quality and product excellence. Keeping such objective in mind, this study proposed to integrate an innovative technology named with virtual reality (VR) to teaching and training engineering students to fulfil industry needs. Virtual reality provides an innovative educational instrument for science [6] that enables students to assess the value of their solutions requiring them to apply relevant knowledge and understanding to a particular real-life complex problem. The interactive 3D environment also provides a suitable tool to break a complex problem into secondary ones and establish relationships between them to create a unique, realistic and practical solution (Park et al., 2013).

Learning through virtual worlds causes positive attitude in learners. It offers to the users cognitive and most out of learning that can engage users in authentic and challenging tasks. In today's increasing number of enrollment to technical education segment creating more challenges to the educational institutions to ensure practical learning aside by theoretical knowledge. Due to

the laggings of practical laboratories, existing laboratories are often overcrowded by students that worsening the overall teaching quality and reducing the teacher's dedication to each of the student. Technical or engineering students demands for the high quality technological profile in order to fit them to compete with hi-tech job markets. There are several cases, where outdated teaching practices create barriers for the students to use interactive technological events. In such situation, application of VR allows students to perform technical activities by their own, which saves teachers time on intrinsic explanations.

This study identified two research questions, which are answered within the scope of this research. First research question was related to the associated benefits and applications of VR in technical education. All the accompanied benefits such as operational safety, apprentice training, risk free hazardous operations, etc., are exclusively experienced through virtual environment. VR technology enables to provide its engineering students with a virtual experiment and training system. It imitates various kinds of real-life engineering challenges that cannot be experimented in traditional classroom or laboratory environment due to cost or health and safety. The implementation of immersive learning process through VR technology can also be used for improving the teaching-learning process that can opens up significant contributions in the field of pedagogy. At this process, teachers could offer their students to designing an effective learning experience. The continual progress of VR through computer graphics and virtual world's technologies can provide the opportunity to learning through virtual laboratories, which can eventually reduce the necessity of real world laboratories.

In order to answer second research question, this study adopted a case example, where it visualized a welding operation through mimicking the real-life welding operation. This case example can be used to offer learners with creative training and learning. The students were very excited with this virtual experiment and showed their motivations during feedback sessions. From this study case, it is noticed that extensive practical knowledge and training can be offered to the engineering students through VR. This technique offers the virtual training to the prospective operators, which contributes to learning process with minimum investment. In order to meet the expectations of learners' in today's digital world, authorities in educational institutions should focus more to adopt digital technologies like VR technology. This technology offers a dual effect by allowing the teachers to improve technical guidance during teaching/training while allow students to offer better learning experiences (Bailey, 2019).

From management point of view, the authorities of institutions can plan their curriculum design in such a way to keep the space for virtual learning environment for the benefits of their learners. During designing the curriculum, considerable amount of budget can be allocated where possible to establish laboratories that support to virtual teaching and learning environment. Although the application of VR is very much useful for learning process through sharing technical knowledge safely but it is quite expensive too. Due to the higher cost, often the implementations of the VR to the higher educational institutions are limited. However, many educational institutions have already implemented this impressive technology for research and educational purposes due to its inherent benefits (Parong and Mayer, 2018; Kizilkaya et al., 2019). As the technology is developing day by day, it is expected that it will be more affordable in the sooner future. In the future research, effort will be taken to look for the possibilities to implement an affordable VR technology suitable for technical education sector with reasonable cost and with reduced complexity. More examples of VR in technical education will also be harnessed for the betterment of engineering students too.

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