Innovation of Mechanical Practice Model using Virtual Reality Technology and Pilot Butt Welding technique in Flat Position

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Abstract: Metal welding is one of the indispensable jobs in daily practice. Nowadays, there are many different welding techniques and methods depending on the object/metal to be welded. This article focuses on studying the principle of butt welding technique of metal plates in the flat position using traditional tools, machinery and equipment, thereby proposing a solution to innovate the practice model of butt welding technique in the flat position with the traditional method on real equipment to the practice method on virtual reality technology. Accordingly, the practical method will design and build 3D models of traditional equipment, tools, and instruments such as soldering irons, current regulators, metal iron blanks, protective gear, etc. using 3D graphic design technologies such as Unity 3D, Maya 3D, 3Ds Max, etc. and build virtual simulation exercises of the metal welding process in the form of a visual virtual reality model using the OpenSG graphics library and C# programming languages. The results of the article will build a virtual reality practice model for butt welding metal plates in a flat position with instructions for automatically explaining each step of the metal welding process. At the same time, the article will also provide assessments and analysis of the quality of the practice exercises at vocational training institutions in Thai Nguyen province.

Keywords: *Butt welding, iron blanks, virtual reality, virtual simulation, 3D model*

I. Introduction

Education and training play a very important role for any country, especially in the current trend of educational streaming, which is professional education and vocational education. In vocational education, the orientation of transforming from training practical skills for people is an inevitable trend to innovate training methods, contributing to improving training quality. In the trend of digital transformation, the 4th industrial revolution has strongly impacted vocational education and training, in which, the main focus is on solutions, published research works, exploiting digital technology solutions into applications to change the way of training vocational skills.

However, to have a complete, objective and accurate view of the exploitation and application of digital transformation technologies, mainly the technologies of the 4th industrial revolution, to support the digital transformation activities of real models to virtual reality (VR) practice models. How is the reality? What is the effectiveness? It requires educational managers and scientists to analyze, evaluate and propose solutions to innovate vocational skills training models. This article is structured as follows: 1). General introduction; 2). Related research works; 3). Research methods; 4). Research results and 5). Conclusions and recommendations.

II. Literature Review

Digital transformation of vocational skills training models based on virtual reality technology is one of the solutions that has brought many effective results in recent years. Evidence shows that both in the world and in the country, it has received much research attention from scientists, experts and education and training managers. Initially, there have been studies and significant achievements in building and developing technological solutions in vocational training practice, specifically:

In the world, Farkhatdinov, I., & Ryu, J. H. (2009); George, A. (2021) have researched and tested the application of virtual reality technology to support mechanical automation practice lessons. The authors Cooper et al., (2019); Athri Nandan, (2020); Demitriadou et al. (2020) have researched the application of information technology, including the use of virtual reality technology to organize virtual classes and the results show the effectiveness and experience of learners. Scaravetti, D. & François, D., (2021) have focused on the research on the use of AR (Augmented

Reality) technology in mechanical engineering. This solution allows learners to learn and interact with lesson content conveniently. The research team applied AR to build solutions that allow the selection of AR devices and software, allowing for a digital chain integrated with the tools and digital files used by mechanical engineers according to Gavish et al. (2021) to practice more proficient skills. VR (Virtual Reality) is an educational technology with significant advances, the application of VR, AR is an important part of the development of professional skills adapted to the context of the technology that engineers must be trained. According to the group of authors (Tao Cheng, 2012; T*u*mler et al., 2021; Washington Quevedo, 2017), it is believed that the application of AR will enhance the interaction of the practice environment, allowing the creation of an effective technological platform for training in the field of mechanics. Applying AR to the design of virtual practice exercises will help learners increase their motivation and joy in learning, exploring, experiencing and visualizing complex phenomena. According to the groups of authors (Wang et al., 2018; Webel et al., 2011 & 2013), it is said that when using AR in practice, it will help learners concentrate more, increase the feeling of ”presence” and improve memory, especially creating advantages to increase learners' motivation and positive attitudes, improve understanding and learning performance, and increase learners' participation. Sabine Webel et al. (2012); Milgram, P. & Kishimo, F. (1994); Neumann, U.& Majoros, A. (1998), discussed the process of creating simulation scenarios for practical lessons, using the real/virtual continuum between tangible and VR interfaces combined with wearable devices to create practical lessons, 3D model representations to support the construction of components in practical lessons and detailed descriptions of the practical lesson process.

Thus, the world has received much attention from scientists and educational managers in vocational skills training activities. They have applied experimental digital technologies such as virtual reality technology to support the digital transformation of traditional vocational training models to virtual vocational training models.

Similar to the world, in Vietnam, vocational training activities in educational institutions have received much attention from many countries, scientists and managers are interested in developing new technology applications such as VR, AR in building simulation software for lessons, mechanical, electrical, welding practices... and have achieved many results. Vocational education and training also needs to change, change training methods and approaches from traditional practice lessons on machinery and equipment in rooms to practice on virtual software. This will partly overcome the current limitations of the lack of facilities and practice equipment. Vocational training facilities have outdated practice equipment, cannot keep up with the trend, and lack the exploitation and development of digital transformation technology applications, 4.0 technology in building virtual reality practice solutions. The project ”Virtual General Physics Laboratory”, by the Institute of Technical Physics - Hanoi University of Science and Technology, built virtual physics experiment software. With liquids, gases . . . and equipment, tools used are completely designed, the process of scientific processing and image authenticity, the experimental operations are simulated ”almost” real. Creating a virtual reality practice environment on the computer according to the Department of Physics and Informatics, (2001). Mimbus Group, 2019], researched solutions to apply virtual reality technology to vocational education training and initially they have produced products such as: Smart classroom solutions, virtual reality simulation systems, supporting human resource training in the automotive mechanical and welding industries . . . with applications designed to provide interactive, hands-on learning experiences. Mechanical engineering simulation system: allows learners to explore mechanical components with 3D simulation objects to develop the fundamentals needed in manufacturing, logistics and maintenance processes, Pneumatic system and equipment simulation system: uses virtual reality models, animations to help learners understand the detailed structure and overall structure of the pneumatic system. The welding practice simulation system runs on the zSpace platform, allowing learners to practice arc welding, with exercises from easy to difficult according to European standards. The most effective simulation welding machine for learning and practicing welding motion skills, the solution allows depending on the selected practice lesson, the software is capable of simulating welding processes. Author groups Nguyen Duong, 2021; V. H. Nguyen and D. T. Vu, (2006) also studied virtual reality technology and initially tested the installation of virtual reality simulation technology applications for a number of occupations, including mechanical engineering. However, the results are only at the research and testing stage, especially the documents used for teaching in technical universities, which are the University of Information Technology and Communications - Thai Nguyen University.

For Thai Nguyen province, where there are many vocational training institutions such as: Thai Nguyen College of Economics and Technology; Viet Duc Industrial College; College of Technology and Commerce; Thai Nguyen Industrial College; Thai Nguyen Vocational College... Through actual surveys, it shows that most training institutions still mainly use traditional equipment and practice machines and some schools still lack practice equipment due to high purchase costs. Up to now, in Thai Nguyen, there has not been any institution that has applied VR and AR technology to support vocational skills practice for learners. These are shortcomings and limitations that require effective investment solutions and changes in vocational skills training models for learners.

Thus, with the analysis both in the world and in the country, it is shown that many educational institutions still do not fully meet the current practical requirements, due to many different reasons such as insufficient finance, not enough students to be able to invest or equip more. Therefore, finding new solutions that are economical and suitable for the reality at each vocational training institution is very necessary.

Within the scope of this paper, only one practical lesson has been selected to pilot the application of virtual reality (VR) technology in building a virtual reality practice lesson with metal welding techniques in the flat position to enhance the practice and experience of learners with welding techniques. Flat position butt welding (symbol - 1G) is widely applied in practice with the advantage of high welding productivity. Therefore, if conditions permit, we should switch to the flat position for welding. Having the skill to butt weld in the flat position will be the initial step in developing the skill. Flat position butt welding is often used in steel structures, where two parts are joined together by welding (Gas Welding Lecture, 2015; M. H. Nguyen, 2012; N. D. Pham & Q. H. Nguyen, 2007). The results of this pilot will be researched, replicated and tested for virtual reality practice with other techniques such as welding, electricity or mechanics . . .

III. METHOD OF BUTT WELDING METAL JOINTS IN FLAT POSITION

1. Method Introduction

Flat position butt welding is a simple welding method widely used in electrical engineering, radio, welding of metal cutting tools, thermal tools, household appliances. Flat position butt welding is the most popular welding method in all welding positions. This is considered a basic weld that any welder must learn.

For flat position butt welding technique, note the following: Depending on the thickness of the welding operation, different welding rods and welding current settings will be selected. You can read more detailed instruction manuals, for example, if welding 3.2 mm rods, the current should be 120 - 140 A.

During the welding process, it is important to keep the arc length stable, oscillating evenly, and not too fast at the edge positions.

The welder can choose the straight or sawtooth welding method. If welding in a straight line, the arc is concentrated in the middle of the weld, so the penetration will be good. If welding in a sawtooth oscillation, attention must be paid to the welding speed to ensure the width of the weld and there must be a stop at the beginning and end points to achieve edge penetration.

For welding materials $> 6mm$ thick or more, to ensure the melting depth, it is necessary to bevel the edges and weld multiple layers. When welding multiple layers, choose a welding rod with a small diameter to weld the first lining layer, move in a straight line, and for the second layer, choose a larger welding rod diameter, move in a straight line or sawtooth, use a short arc to weld. Note that each layer of weld should not be too thick.

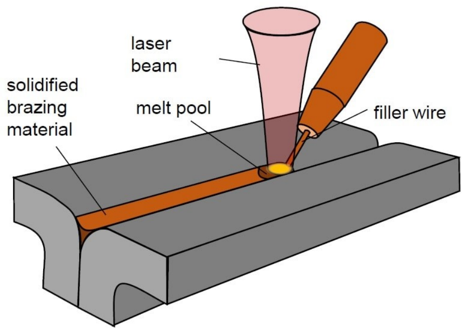


Figure 1. Metal welding model by butt welding in flat position.

For flat position butt welding is often used in steel structures, where two parts are joined together by welding. To ensure the durability and stability of the weld, you need to pay attention to the following factors:

1. **Welding type**: Spot welding, continuous welding or U-shaped welding can be used depending on the technical requirements and load of the structure.
2. **Weld size**: Weld size needs to be calculated to have sufficient strength according to design standards.
3. **Surface preparation**: The surface of the parts needs to be cleaned to ensure good weld adhesion.
4. **Welding procedure**: Standard welding procedure must be followed, including temperature adjustment, welding speed and welding time.
5. **Quality check**: After welding is complete, the weld should be inspected to ensure there are no defects such as cracks, porosity or missing weld material.

For flat position metal butt welding technique, to ensure weld quality, welding engineers need to pay attention to choosing:

+ **Welding rod angle**: The welder needs to maintain the correct welding rod angle and stable arc length (Lhq=2 ~ 4 mm) throughout the welding process; Correctly perform the welding seam connection operation; When the welding seam is finished, the weld pool must be filled.

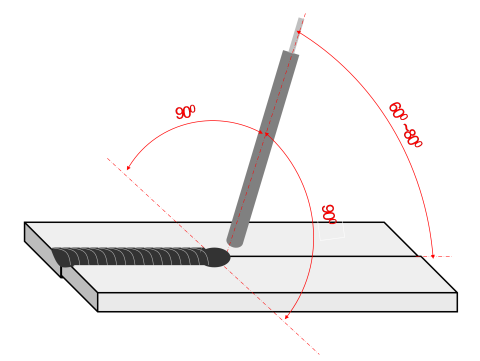


Figure 2. Illustration of welding rod angle.

+ **Transverse oscillation of the welding rod**: To ensure the weld penetration, when welding the welding rod can oscillate in a straight line or a sawtooth oscillation. If it follows a straight line, the arc is concentrated in the middle of the weld, so the penetration in this case is better. When oscillating in a sawtooth shape, the welding speed must be appropriate (to ensure the weld width) and there must be a stop on both sides to achieve the weld edge penetration.

2. Butt welding technique of metal joints in flat position

To weld two metal plates/iron pieces into one, we need to follow the following sequential steps:

- Step 1- Preparation: Welding table, iron piece, welding head, ground wire, welding machine, welding rod, protective equipment, other items. Check and install equipment. Make sure the equipment is working well and safely and is checked periodically.
- Step 2- Determine the weld line: This can be done using a template or marking directly on the metal surface.
- Step 3- Connect and adjust the welding machine: Connect and adjust the current to suit the welding workpiece as well as the welding rod with the equipment, ensuring that the equipment wires are connected together.
- Step 4- Fix the welding blank: welding to avoid the welding blank from shifting, also to ensure the best welding line, correct technique and high aesthetics.
- Step 5- Welding: tilt the welding rod tip at a 65 degree angle to the welding workpiece, dot each point along the edge of the 2 pieces of workpiece at the welding position, each position overlaps about 50%.
- Step 6- Welding slag removal process: After welding is complete, turn off the equipment to ensure safety and remove the welding slag at the welding site, exposing the weld.
- Step 7- Check the results: Check the weld to ensure that it meets the requirements of the exercise and has no unwanted marks.

Some notes on butt welding instructions in flat position:

How to choose solder scales: When choosing solder scales, you need to base on the technical conditions of the weld as well as the working environment of the object to be able to choose the appropriate solder scales for the requirements of the weld.

Soldering mode: In soldering mode, the most important factors are the welding temperature, welding time, melting temperature of the solder and solder scales, and finally the heating rate.

- The welding temperature is a definite quantity and the welding temperature will be greater than the temperature of the solder.
- The heating time will depend on the factors such as the size of the solder, the gap between the solder, the metal composition of the solder and the solder.
- The heating speed will depend on the size of the solder, the thermal conductivity of the solder and the requirements of the welding technique.

Heating method: To have a beautiful weld, it is necessary to ensure 3 factors: good weld structure, suitable weld scale and good heating method. Therefore, the heating method is extremely important. If the weld structure is good, the weld scale is suitable but the heating is not good, the quality of the weld will also be poor.

For the best quality weld, when heating, it is necessary to heat evenly on all sides of the welding machine, the weld and the weld scale.

Weld structure: The important factor determining the strength of the weld is the weld cross-section and the adjustment of the connections together.

IV. Results

1. Collect image data about tools, equipment, and facilities

The lesson on butt welding of metal joints in the flat position usually uses the tools, apparatus or equipment as shown Figure 4.

In addition to the above tools, instruments, and equipment,

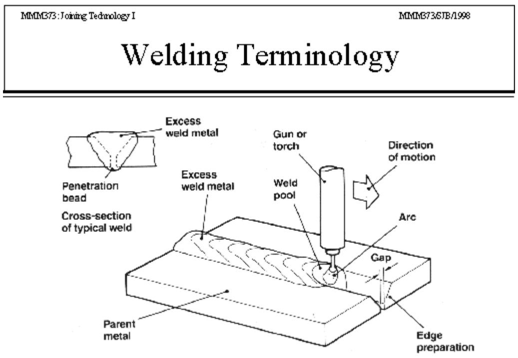


Figure 3. Weld structure.

Figure 4. Some tools and equipment commonly used in flat position butt welding.

many other equipment are also used to practice the lesson of welding metal joints in the same position. Figure ?? illustrates some of the above equipment and instruments, which the research team collected images and models using scanners, 3D scans, and cameras to take pictures.

2. Design 3D models of tools, instruments, and components used in virtual practice

Based on the images of tools, equipment, and machinery components used in the practice of butt welding metal joints in flat positions, perform the following main steps:

Figure 5 illustrates the process of creating 3D models of tools, equipment, and facilities:

Based on the images of tools, equipment, and machinery components used in the practice of butt welding metal joints in flat positions, perform the following main steps:

Step 1: Map the actual photos into graphics software such as Photoshop, 3Ds Max, Maya 3D... to process noise, fine-tune each component to ensure the actual size of the tool.

Step 2: Build 3D models of tools such as tables, iron blanks, etc.

Step 3: Perform processing, mesh optimization and material coating (texture) on the surface of each tool model.

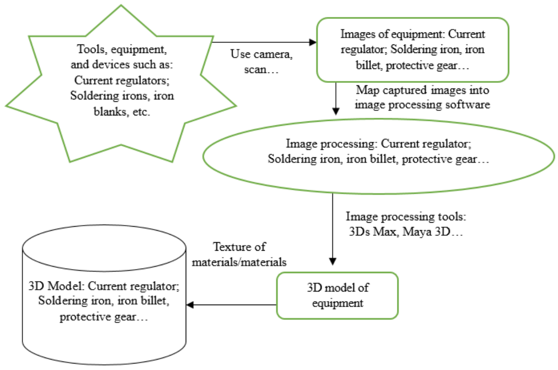
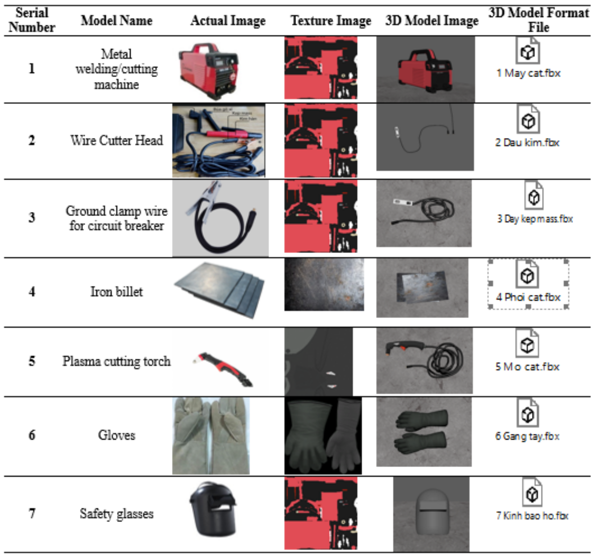


Figure 5. Virtualization process, creating interactive 3D models.

Step 4: Evaluate the 3D model results with images of each actual tool to see if the quality is guaranteed.



Serial Number	Model Name	Actual Image	Texture Image	3D Model Image	3D Model Format File
1	Metal welding/cutting machine				1 May cat.fbx
2	Wire Cutter Head				2 Dau kim.fbx
3	Ground clamp wire for circuit breaker				3 Day kep mass.fbx
4	Iron billet				4 Phoi cat.fbx
5	Plasma cutting torch				5 Mo cat.fbx
6	Gloves				6 Gang tay.fbx
7	Safety glasses				7 Kinh bao ho.fbx

Figure 6. Some 3D models of tools built for use in the practice of butt welding metal joints in flat position.

With 3D models of each tool, apparatus, and component used in the metal butt welding practice in a flat position (Figure 6), the group of authors will rely on the scenario and teaching plan of the practice to design and build a virtual practice using Unity 3D technology and C# programming.

3. Solution to convert number of practice exercises on metal butt welding in flat position

With 3D models of tools, equipment, and equipment used in the practice of welding metal using gas welding techniques, the group of authors proceeded to build steps to convert the practice from traditional form to virtual reality practice using virtual reality programming technology. With the technique of welding metal blanks in the flat position, it is modeled by the algorithm flowchart below Figure 7. Below are some simulation results illustrating in detail in

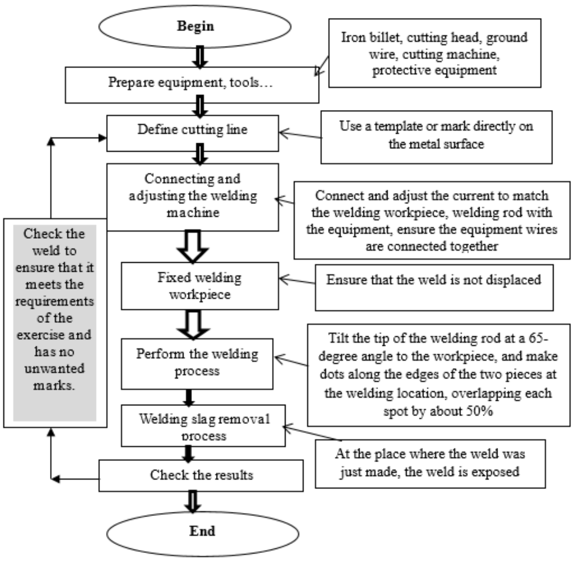


Figure 7. Algorithm flowchart simulating the metal butt welding process in flat position.

Figure 7 the progress of performing the metal butt welding practice in position using virtual reality technology. First step: Prepare the necessary 3D tools and equipment used in the exercise (Figure 8); determine the welding line and connect the current adjustment . . .

Figure 8. List of 3D tools and instruments.

3D models of tools and equipment: 3D models of tools, equipment and components including Electric arc metal welding machine, Wire welding pliers, Iron workpiece, Plasma welding torch, gloves, welding glasses... have been built from Figure 6.

Next steps: Perform metal butt welding in a flat position along the predetermined weld line.

Based on the steps of the metal butt welding method in the flat position and based on the algorithmic flowchart simulating the metal butt welding process in the flat position in Figure 7, the research group proceeded to build a virtual practice using virtual reality technology and other technologies including:

1) The group of software tools for creating 3D models and tools includes 3Ds max used for creating shapes, Zbrush used for creating shapes and convexities ..., Subtance Painter used for creating materials and Maya used for creating movement and animation.
2) The programming technology group builds virtual, interactive practice lessons including C#, Unity 3D Engine, VRML... used to program the control of initializing 3D models into the virtual reality environment and program the control of camera settings, interacting with 3D tools, and virtual practice process steps.

Below is a diagram detailing the process from preparation to the final step to achieve welding results:

The above process diagram describes each specific step

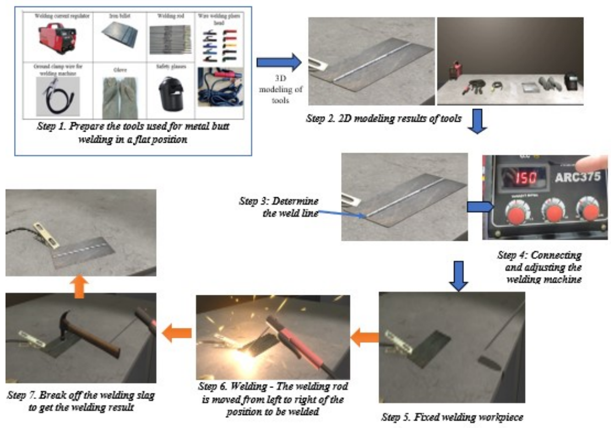


Figure 9. Diagram detailing the steps of the metal butt welding process in the flat position from the start to the result of the butt welded metal plate.

in detail with illustrations of the results of the metal butt welding process in the flat position. In particular, the process ensures that the main steps of the metal butt welding method are followed correctly.

Below is an illustration of the resulting sheet metal after welding:

4. Evaluation of virtual simulation program for metal butt welding practice in flat position

Part 4 presented the construction of a virtual simulation program for the practice of metal butt welding in a flat position, which was built on the basis of studying the content of traditional practice lessons, from which multimedia tools such as cameras, scanners, etc. were used to collect tools, instruments, and related components used in

Figure 10. Image of the butt-welded metal plate in the flat position after the slag has been removed.

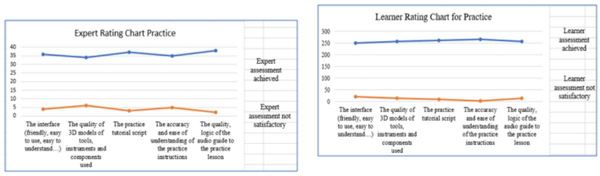
the practice lesson, and to build a 3D model of each tool and component. On that basis, the design, arrangement, and assembly of the virtual reality practice of metal butt welding in a flat position were carried out.

In order to evaluate and test the virtual reality practice on metal butt welding in a flat position, the group of authors has built a group of 5 criteria on friendliness, ease of use, model quality, practice instruction script, etc. The group of authors has designed a survey form to distribute and investigate scientists, education experts and related learners. Through organizing a scientific workshop, presenting in detail the virtual reality practice software on metal butt welding in a flat position. Then, the survey form is distributed. At the workshop, the group of authors invited about 40 experts, scientists, teachers with specialized knowledge related to welding, electrical, mechanical engineers, etc. and 270 learners from 5 colleges and vocational schools in Thai Nguyen province that provide training in electrical, mechanical, welding, etc.

The scientific workshop focused on presenting two main topics: an overview of the content of the traditional practical lesson teaching script and running a program introducing the main functions guiding the virtual vocational training skills practice of metal butt welding in a flat position on a simulation software environment. The results received were evaluated by 40 experts, scientists, teachers and 270 students from 5 colleges and vocational schools in Thai Nguyen province that provide training in electricity, mechanics, welding, etc. The evaluation results and comments are illustrated in Figure 11 and Figure 12. Thus, the

Survey criteria	Expert assessment achieved (%)	Expert assessment not satisfactory	Learner assessment achieved (%)	Learner assessment not satisfactory
The interface (friendly, easy to use, easy to understand...)	36 (90%)	4	250 (93%)	20
The quality of 3D models of tools, instruments and components used	34 (85%)	6	257 (95%)	13
The practice tutorial script	37 (93%)	3	262 (97%)	8
The accuracy and ease of understanding of the practice instructions	35 (88%)	5	267 (99%)	3
The quality, logic of the audio guide to the practice lesson	38 (95%)	2	256 (95%)	14

Figure 11. Summary of survey results.



a) Expert assessment survey *b) Student assessment survey*

Figure 12. Evaluation chart of virtual reality practice simulation system.

chart in Figure 12 shows that the virtual reality simulation system for metal butt welding in a flat position ensures the evaluation criteria of quality, interface, teaching scenario... ensuring quality and is highly evaluated. Figure 11 also shows the results of the evaluation survey of experts and learners with a high rate of evaluation of quality such as:

- Regarding the interface (friendly, easy to use, easy to understand...): Up to 90% of experts, scientists and teachers rated it as satisfactory; up to 93% of learners rated it as satisfactory, the remaining 7% of learners suggested that it should be adjusted to be more friendly.

- Regarding the quality of 3D models of tools, instruments and components used in the practice: Up to 85% of experts, scientists and teachers assessed the 3D models as satisfactory; up to 95% of learners assessed the 3D models as satisfactory, the remaining 5% of learners should suggest further revisions.

- Regarding the practice instruction script: Up to 93% of experts, scientists and teachers assessed the instruction script as satisfactory; up to 97% of learners assessed the instruction script as satisfactory, the remaining 3% of learners assessed it as unsatisfactory.

- Regarding the accuracy and ease of understanding of the practice instructions: Up to 88% of experts, scientists and teachers assessed it as satisfactory; up to 99% of learners assessed it as satisfactory, the remaining 1% of learners should suggest further revisions.

- Regarding the quality and logic of the audio guide to the practice lesson: Up to 95% of experts, scientists and teachers assessed that it met the requirements; up to 95% of learners assessed that it met the requirements, while the remaining 5% of learners assessed that it did not meet the requirements.

V. Conclusion

Vocational training is one of the important tasks for any country and for our country it is even more important and education and training in general has become a top national policy. Over the years, our country's education and training have changed a lot, contributing a large amount of human resources and labor to the country. And in particular, education has had changes in development and application of achievements of science and technology to promote development, approach innovation and creativity. Besides the work that has been done in education in Vietnam in general and vocational education in particular, we need to have many more changes. Approaching education in a vocational direction, meeting social needs and needing to change the methods and ways of training theory combined with vocational practice based on technology and reality in enterprises.

This article focuses on researching and proposing solutions to apply digital transformation technology and virtual reality to build a virtual practice model on a technology platform using graphic design software such as Unity 3D, 3Ds Max, Maya 3D and control programming languages such as C#... The article has chosen to pilot the construction of a virtual reality practice lesson for the metal butt welding profession in a flat position. The results of the virtual reality practice lesson have been evaluated by 40 experts, scientists, and teachers currently teaching at vocational education institutions and tested for 5 classes with 270 learners asked for their opinions. The evaluation results have been summarized, analyzed and commented on in section IV.4, showing that the virtual simulation system of the metal butt welding practice in the flat position has met the requirements and ensured quality. Through the virtual reality practice system, learners can grasp knowledge and approach the application of the practice faster, mastering the practical skills of the lesson better.

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REFERENCES

[1] A. Nandan, “Best software courses for mechanical engineering students,” Skyfi Education Labs, 2020. [Online]. Available: https://www.skyfilabs.com/blog/best-software-courses-for-mechanical-engineering-students

[2] G. Cooper, H. Park, Z. Nasr, L.-P. Thong, and R. Johnson, “Using virtual reality in the classroom: Preservice teachers’ perceptions of its use as a teaching and learning tool,” *Educational Media International*, vol. 56, pp. 1–13, 2019.

[3] E. Demitriadou, K. E. Stavroulia, and A. Lanitis, “Comparative evaluation of virtual and augmented reality for teaching mathematics in primary education,” *Education and Information Technologies*, vol. 25, pp. 381–401, 2020.

[4] Department of Physics and Informatics, “Application of IT in teaching,” Center for High Performance Computing, ITIMS Informatics Group, Hanoi, 2001.

[5] I. Farkhatdinov and J. H. Ryu, “Development of an educational system for automotive engineering based on augmented reality,” in *Proc. Int. Conf. Engineering Education and Research*, 2009.

[6] A. George, “Lockheed is using these augmented reality glasses to build fighter jets,” *Popular Mechanics*, 2021. [Online]. Available: https://www.popularmechanics.com. [Accessed: Aug. 1, 2021].

[7] “Gas welding lecture – Lesson 2.2: Butt welding using gas welding method in flat welding position,” 2015. [Online]. Available: https://tailieu.vn/doc/bai-giang-han-khi-bai-2-2-han-giap-moi-bang-phuong-phap-han-khi-o-vi-tri-han-bang-2561176.html

[8] N. Gavish *et al.*, “Evaluating virtual reality and augmented reality training for industrial maintenance and assembly tasks,” *Interactive Learning Environments*, vol. 23, pp. 778–798, 2015.

[9] P. Milgram and F. Kishino, “A taxonomy of mixed reality visual displays,” *IEICE Trans. Information Systems*, vol. 77, pp. 1321–1329, 1994.

[10] M. H. Nguyen, “Lecture on manufacturing technology,” College of Economics and Technology, Thai Nguyen University, 2012.

[11] U. Neumann and A. Majoros, “Cognitive, performance, and systems issues for augmented reality applications in manufacturing and maintenance,” in *Proc. IEEE Virtual Reality Annual Int. Symp.*, Atlanta, GA, USA, pp. 4–11, Mar. 1998.

[12] D. Nguyen, “Application of VR/AR/MR technologies in modern industries,” 2021. [Online]. Available: https://onetech.vn/blog/ung-dung-cong-nghe-vr-ar-mr-cho-cac-nganh-nghe-13548

[13] M. Nebeling *et al.*, “XRDirector: A role-based collaborative immersive authoring system,” in *Proc. CHI Conf. Human Factors in Computing Systems*, Honolulu, HI, USA, Apr. 2020.

[14] N. D. Pham and Q. H. Nguyen, *Textbook on Machine Manufacturing Technology*. Hanoi, Vietnam: Hanoi Publishing House, 2007.

[15] D. Scaravetti and D. Doroszewski, “Augmented reality experiments in higher education for complex system appropriation in mechanical design,” in *Proc. CIRP Design Conf.*, Póvoa do Varzim, Portugal, May 2019.

[16] S. Webel *et al.*, “An augmented reality training platform for assembly and maintenance skills,” Fraunhofer IGD, Germany, 2012. [Online]. Available: https://mimbus.vn. [Accessed: Jun. 25, 2019].

[17] T. Cheng and J. Teizer, “Real-time resource location data collection and visualization technology for construction safety and activity monitoring,” *Automation in Construction*, 2012.

[18] J. Tumler *et al.*, “Mobile augmented reality in industrial applications: Approaches for solving user-related issues,” in *Proc. IEEE/ACM ISMAR*, Cambridge, UK, pp. 87–90, Sep. 2008.

[19] V. H. Nguyen and D. T. Vu, *Real-world simulation programming techniques based on Morfit 3D*. Hanoi, Vietnam: Science and Technology Publishing House, 2006.

[20] W. Quevedo, “Teaching–learning process through VR applied to automotive engineering,” in *Lecture Notes in Computer Science*, 2017, doi: 10.1007/978-3-319-60922-5_14.

[21] M. Wang *et al.*, “Augmented reality in education and training: Pedagogical approaches and illustrative case studies,” *Journal of Ambient Intelligence and Humanized Computing*, vol. 9, pp. 1391–1402, 2018.

[22] S. Webel *et al.*, “Augmented reality training for assembly and maintenance skills,” *BIO Web of Conferences*, vol. 1, p. 97, 2011.

[23] S. Webel *et al.*, “An augmented reality training platform for assembly and maintenance skills,” *Robotics and Autonomous Systems*, vol. 61, pp. 398–403, 2013.

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