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Research Article

Innovation in Teaching Methods for Practical Metal Welding Lessons using Gas Welding Teachniques using Virtual Reality Technology

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ABSTRACT

This paper focuses on studying the principles of traditional gas welding methods using traditional tools, machinery and equipment, thereby proposing solutions to innovate the practice of traditional gas welding techniques to gas welding techniques using virtual reality technology. Accordingly, the practical method will design and build 3D models of traditional equipment, tools and instruments such as: soldering irons, gas cylinders, metal iron blanks, protective gear... using 3D graphic design technologies such as Unity 3D, Maya 3D, 3Ds Max... and proceed to build virtual simulation exercises of the welding process of metal bars in the form of visual virtual reality models using programming languages such as C#.

The paper also presents the results of evaluation and testing of the simulation program Virtual simulation of metal welding practice using gas welding techniques based on scientific seminars, with participation and comments from educational experts at vocational education institutions, scientists, Teachers and students studying mechanics, electricity, welding...

Keywords: Gas welding; metal welding; virtual reality; virtual simulation; 3D modeling.

INTRODUCTION

Digital transformation plays a very important role, affecting all aspects and areas of social life, it changes the way we live, work and relate to each other. In the field of education in general and vocational education in particular, digital transformation has created new ways and methods of education and training, creating many new methods of implementation and operation in training activities, especially during the period of prolonged Covid 19 pandemic, social distancing, and education and training closure (Mikalef and Parmiggiani, (2022)). Therefore, to ensure regular, continuous and effective operations without interruption in training activities, the education sector has quickly converted training forms and methods from traditional to online/distance training, e-learning, blended training, etc. That means all activities from management, teaching, practice guidance, assessment... are all carried out through electronic means, internet, etc (Peter et al. (2019)).

However, during those periods, educational institutions mainly used tools, means or free software, exploiting simple software such as: zoom, teams, google meeting... to support sharing, presenting lectures with slides to teach theoretical lessons, while practical lectures have not been converted or even difficult/impossible to convert to the form of lectures, teaching instructions online/from the commune or online. The reason is that vocational training institutions do not have tools, programs, equipment, or virtual or remote practice equipment... using models and simulations that are digitally converted from traditional practice exercises (Yi Wang et al. (2019)). Therefore, practical lessons could not be carried out at that time. This is one of the limitations and shortcomings of educational and training institutions in general and vocational education institutions in particular. In order to overcome the above shortcomings and limitations, one of the effective solutions is to digitally convert traditional practice lessons using current equipment, tools and instruments into virtual reality practice models, supporting online/remote

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practice instructions via electronic means and the internet. The article will select proposals for digital transformation and piloting practical lessons on metal welding skills using gas welding techniques in vocational education institutions in the current period.

THEORETICAL FRAMEWORK

Welding is a technology to join metal or non-metal machine parts together by heating the joint to a welding state. Then the metal solidifies or through pressure, the joint creates a strong bond called a weld. Gas welding is one of the fusion welding methods, in which the heating of the metal area to be welded to the welding state is done by a flame of combustible gases with oxygen. Welding rod is a metal rod of the same material as the metal being welded that is also melted together with the weld metal to form the weld. Gas welding is a chemical welding method that uses the heat of combustion reaction of gas in oxygen to melt the metal components being welded and the additional welding rod to form the weld. Gas welding is a welding method that uses the heat of a flame generated when burning combustible gases (C_2H_2, CH_4, ...) or with Oxygen for melting metals (Pham and Nguyen, 2007; Nguyen (2012), Orszagh et al. (1998)).

There are many different welding methods, with different names such as gas welding, gas welding, gas welding, oxygen welding... This article focuses on the characteristics of the gas welding method, also known as gas welding. With the gas welding method: it is relatively special because it may not require the use of welding rods. Instead, during the welding process, people will use oxygen gas combined with another combustible gas such as hydrogen, acetylene, benzene gas, gasoline vapor or coal gas. The Oxy-Acetylene welding method is based on the exothermic chemical reaction of oxygen gas and other combustible gases, causing the temperature of the material to be welded to increase rapidly. The metal part at the welding position will melt and bond together to form a weld after cooling (Pham and Nguyen, 2007; Nguyen (2012), Orszagh et al. (1998)).

The gas welding method can work on many different materials and is only suitable for thin metals with low melting temperatures. However, investing in equipment for gas welding is much more economical than similar welding techniques. For the method of welding metals using gas welding: it is necessary to pay attention to two types of gases, which are oxygen used to maintain combustion and combustible gases such as acetylene [C_2H_2], hydro [H_2], coal gas, gasoline vapor and benzene... in fact the main gas used for welding is acetylene because when this gas burns in oxygen it releases the least amount of heat [11470 cal/m3] and bring the temperature to the highest level [3150oC]. Hydrogen gas is a colorless, odorless gas (Lin et al. (2009), Tong et al. (2002)).

The method of welding metals using gas welding techniques is applied daily in practice and has been applied in vocational education and training in many vocational training institutions, aiming to train human resources for the country. Along with the digital transformation trend, vocational education activities have had positive changes, researching and exploiting digital technology solutions to build virtual practice lessons for different vocational lessons to contribute to improving the quality of vocational skills training for learners. In the world, the group of authors Wang et al. (2018) has studied the application of virtual reality technology in the design of exercises, thereby helping learners to concentrate more, increase the sense of "presence" and improve memory (Johnson et al. (2016), especially creating advantages in increasing learners' motivation and positive attitudes, improving their understanding and learning performance, and enhancing learners' participation. In 2021, the group of authors Scaravetti and François (2021) also used virtual reality technology to support mechanical engineering vocational training, allowing the construction of practical lessons to support learners to interact with lesson content in a virtual environment according to the process of Washington Quevedo (2017), Azuma (1997), Nicolas Vignais et al. (2013). Applying virtual reality or augmented reality technology to the design and construction of virtual practice lessons will help learners increase their motivation and joy in learning, exploring, experiencing and visualizing complex phenomena, exercises and practice processes. The Milgram and Kishimo (1994) also initially discussed the process of creating AR scenarios from CAD data, using the real/virtual continuum between tangible interfaces and virtual reality technology, wearable devices (head-mounted displays with gesture recognition) and virtual reality technology devices processed to create practice exercises. Nebeling et al. (2020), Imottesjo et al. (2020) used CAD(Computer Aided Design) software technology to represent, display 3D models to support the construction of detailed parts in practical lectures and describe the detailed operation process. CAD is a software used to design products using the tools and features of the software. CAD allows engineers and designers to create 3D models or technical drawings on

computers, simulate, evaluate and perfect their designs accurately. Thus, in the world, digital transformation activities in vocational education and training, vocational skills for learners have also received much research attention and have achieved many of the results indicated above.

In Vietnam, as well as in the world, vocational education has also received much attention from managers and scientists from central to local levels, especially the ministries/sectors managing education have had many directives and strategic orientations on innovation in teaching methods, innovation in guidance models, and education and training streaming nationwide using digital transformation technology. Especially the timely direction and management to respond to the changes and impacts of digital transformation technology, the 4th industrial revolution in building solutions to apply technology to change training methods and methods from traditional practice exercises on equipment and machinery in practice rooms to exploiting practice on virtual reality practice guidance software, creating virtual practice and experiment environments on computers (Wang et al. (2010)). Mimbus specializes in researching solutions for applying virtual reality technology to vocational training and initially they have released products such as: Smart classroom solutions, virtual reality simulation systems, support workforce training in the automotive, welding, healthcare and pharmaceutical 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 fundamental principles needed in manufacturing, logistics and maintenance processes (http://www.vrsolutions.vn). Pneumatic system and equipment simulation system: using virtual reality models and animations to help learners understand the detailed structure and overall components of the pneumatic system (http://www.vrsolutions.vn). Welding practice simulation system: welding simulation running on zSpace platform, allowing learners to practice arc welding, with exercises from easy to difficult according to European standards. The most effective welding simulator for learning and practicing welding motion skills, the solution allows depending on the selected practical lesson, the software is capable of simulating welding processes with step-by-step instructions on a digital platform.

In Thai Nguyen, 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 practical surveys, it is shown that most practical training facilities still mainly use traditional equipment and machinery in practice rooms, and some schools still lack practical equipment due to high purchase costs. Furthermore, within 5 years, it must be changed, updated, and improved to meet practical requirements. Up to now, no vocational training institution in Thai Nguyen has applied virtual reality or augmented reality technology to support vocational skills training practice for learners (V. H. Nguyen and D. T. Vu, (2006)). This is one of the shortcomings and limitations that requires effective investment solutions and changes in vocational skills training models for learners. The solution of applying digital transformation technology and 4.0 technology to build practical, modern, virtual/remote practice solutions to support vocational training institutions will partly overcome the lack of practice and experimental equipment, which is outdated and cannot keep up with the trend.

Thus, through analysis both in the world and in the country, in Thai Nguyen province, it is shown that many educational institutions still do not fully meet current practical requirements, due to many different reasons such as: financial limitations, the number of students studying to be able to invest or equip more... Therefore, finding new, economical and practical solutions at each vocational training institution is very necessary. This paper focuses on digital transformation of metal welding methods using gas welding techniques using virtual reality technology.

METHODOLOGY

METHOD INTRODUCTION

- Gas welding technology:

Any welding technique requires technology or equipment, tools, and instruments to serve the welding process. The quality of each gas weld depends on the selection of the welding torch power, the quality of the welding rod, the adjustment of the welding flame, the selection of the welding method, and the tilt of the welding torch (Xu et al. (2014), Pal et al. (2008), Pal et al. (2007)).

Gas welding technique includes two main methods, which are right-hand welding and left-hand welding.

Right welding: start welding from left to right, that is, the welding torch moves first, the welding rod moves later. This method is highly productive and saves acetylene gas. At the same time, the weld after welding is heated by the flame for a while, so the weld's flexibility is increased and it is less likely to crack.

Left welding: start welding from right to left [welding rod moves in front of the welding torch]. Welding speed by this method is relatively slow [usually 20-30% slower than right welding] and is usually only used to weld thin objects [3mm or less], non-ferrous metals such as aluminum, zinc, etc.

- ❖ Preparation before welding:

To carry out gas welding, we need to prepare in advance, have equipment, protective gear... Must be fully equipped from clothes, glasses to specialized gloves for welding work.

Next, everyone must ensure that the equipment and welding accessories are clean and free of grease. At the same time, the surface of the working material must also be thoroughly cleaned.

Finally, the gas cylinder used in the welding process must ensure that the pressure valve is loosened and the safety cap is tightly secured. Absolutely do not work if damage is detected on these parts or when the gas cylinder shows signs of leakage.

- ❖ Gas welding equipment:

Acetylene is prepared by reacting calcium carbide with water. Calcium carbide is produced by melting limestone with charcoal in an electric furnace. Calcium carbide is a gray-black stone, very hard, and difficult to react with acids, but when exposed to water and moisture in the air, it will produce acetylene gas 0,3%. To avoid the explosion of calcium carbide containers, the containers must be kept very tightly sealed, placed in a well-ventilated, dry place, high above the ground, and absolutely not placed in a humid or airtight place. There must be a separate room for the calcium carbide container.

Acetylene gas is supplied to the welding site from acetylene gas cylinders or acetylene gas cylinders in acetone solution under pressure of 16-22 atm. The acetylene gas contained in this cylinder is very convenient to use, just need to install a pressure reducing valve to be able to use, after using up, the cylinder can still be brought back to the workshop to be refilled with gas.

Oxygen is a colorless, odorless, non-toxic gas that cannot burn by itself, but helps combustion. Oxygen is present in the air at about 21% [by volume], the oxygen used in welding is pure oxygen prepared from air by: press, cool, expand to make air liquid, then evaporate at -1830C to obtain pure oxygen. When that oxygen is contained in a 40 liter steel tank [oxygen tank] with a pressure of 150 at and brought to the welding site.

- ❖ Introduction to gas welding components installation:

The equipment of the method is simple but the economic application field is very wide. With this method we can weld in all positions, especially in the manufacture of pipelines, thin-walled vehicle structures, as well as in maintenance installation and welding. The materials that can be welded with this method are also very diverse such as: low alloy steel, copper, aluminum, cast iron (details in figure 1).

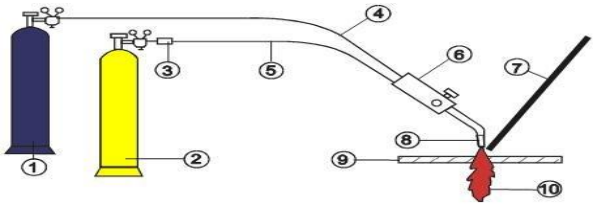


Figure 1: How to install welding components. *(1). Oxygen cylinder with pressure reducing valve; (2). Acetylene cylinder with pressure reducing valve; (3). Pre-regulating device; (4). Oxygen hose; (5). Acetylene hose; (6). Welding torch; (7). Welding rod; (8). Welding rod; (9). Welding parts and (10). Welding flame.*

GAS WELDING TECHNIQUE

To perform the gas welding process, the welder needs to follow the following detailed steps:

Step 1: Prepare tools, equipment, and 3D modeling equipment such as: Choosing welding rods suitable for welding workpieces, copper or aluminum materials, welding torches, gas cylinders, gloves, welding glasses...

Step 2: Build a script for the welding machine startup states such as: Open the welding gas valve to ignite the welding torch, Light the ignition on the welding head, adjust the gas, welding current corresponding to the material thickness and oxygen gas to create blue sparks.

Step 3 Perform Heating and cleaning of the welding workpiece.

Step 4: Perform the welding process: Place the tip of the welding rod in the position that needs to be welded on the welding workpiece, slowly insert the welding rod into the position that needs to be welded, place the welding rod about 70 degrees along the surface of the welding object and continuously move the welding torch from left to right so that the welding rod flows out and sticks to the welding workpiece.

Step 5: Check the weld when the weld is complete, quickly remove the soldering iron from the welding position and finish the welding process.

Step 6: Close the welding gas valve and turn off the welding machine.

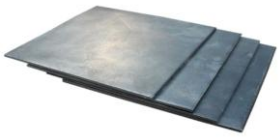
❖ *Some notes:* After completing the welding process, the temperature of the soldering iron before completing the welding work. During the welding process, it is important to note that the soldering iron temperature should not be too high. The writer's experience is to prepare a water tank in advance to quickly cool the soldering iron when this happens. When welding, from the step of placing the soldering iron and the soldering iron, welding from right to left will bring higher efficiency.

RESULTS AND DISCUSSION

RESULTS

Collect image data about tools, equipment, and facilities: In the lesson on metal welding by gas welding technique, tools, instruments or equipment used in the teaching and practice of metal welding by gas welding technique are often used in Table 1:

Table 1. *Some tools and equipment commonly used in welding metals using gas welding techniques*

Gas welding equipment set	**Soldering iron set**	**Iron billet**
		
Copper welding rod or aluminum welding rod	**Glove**	**Goggles**
		

3D Modeling: Based on images of tools, equipment, and machinery components used in the practice of welding metal using gas welding techniques. The authors performed the following steps to build 3D models of tools and equipment for the practice of welding metal using gas welding techniques:

Step 1: Select tools, equipment, and facilities for the practice session

Step 2: Take pictures of tools, equipment, and supplies for practice

Step 3: Digitally convert real photos into graphic software such as photoshops, 3Ds Max, Maya 3D to process noise, fine-tune each component to ensure the actual size of the tool.

Step 4: Create 3D models of tools, instruments, equipment

Step 5: Apply materials, textures to the surface of the model.

Step 6: Evaluate 3D models against images of actual instruments to ensure quality.

Process of creating 3D models of tools, equipment, and practice equipment (details in figure 2):

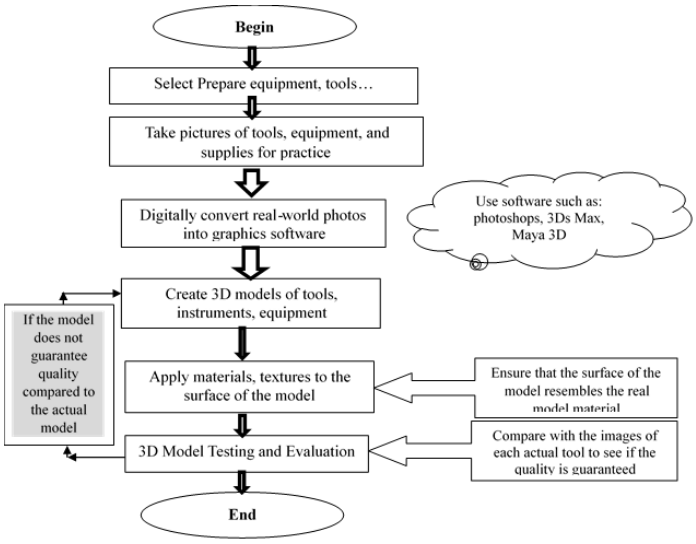
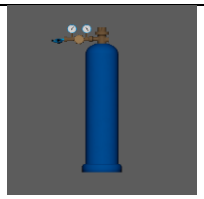
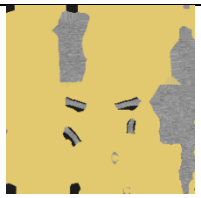
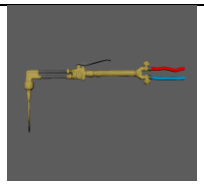
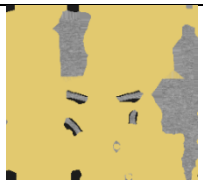
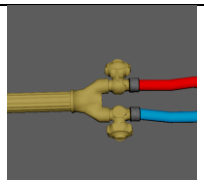
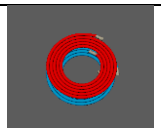
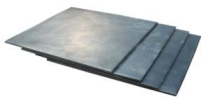
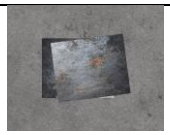
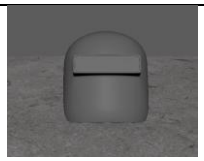


Figure 2: Illustrates a flowchart that guides the creation of 3D models of equipment, tools, and instruments.

Table 2. *Some 3D models of tools built and used in the metal welding practice:*

Sequence	Model Name	Actual photo	Texture	3D model photo	3D model format file
1	Gas bottle				1 Binh gas.fbx
2	Scuba				2 Binh khi.fbx
3	Soldering iron				3 Mo han.fbx
4	Gas and air line connector				4 Dau noi day.fbx

5	Gas cylinder and gas hose				5 Day noi.fbx
6	Cutting blank				6 Phoi cat.fbx
7	Lighter				7 Bat lua.fbx
8	Gloves				8 Gang tay.fbx
9	Goggles				9 Kinh bao ho.fbx
10	Copper aluminum welding rod				10 Que han.fbx

Source: Authors, 2024

With 3D models of each tool, apparatus, and component used in the metal welding practice using gas welding techniques (Table 2), the group of authors will rely on the scenario and teaching plan of the practice to design and build a virtual practice using virtual reality technology such as: Unity 3D, programming C#.

Digital transformation solution for metal welding practice using gas welding technique using virtual reality technology:

Based on 3D models of tools, equipment, and devices used in metal welding exercises using gas welding techniques, the group of authors proceeded to build steps to convert the number of exercises from traditional form to virtual reality practice using virtual reality programming technology (Illustration see details in figure 3).

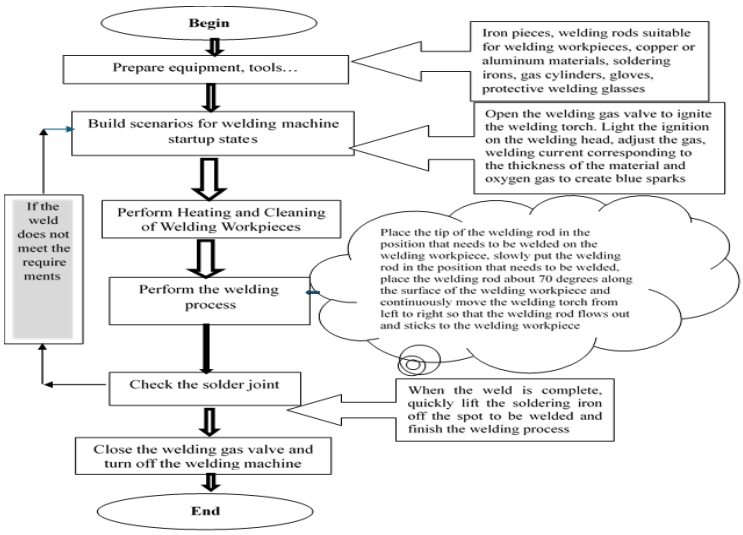


Figure 3: With the metal welding technique using gas welding technique is modeled by the algorithm flowchart

Below are some simulation results illustrating in detail in Figure 3 the progress of performing the metal welding practice using gas welding technique using virtual reality technology.

First step: Prepare the necessary 3D tools and equipment used in the practice; welding rods suitable for the welding workpiece, copper or aluminum materials, welding torches, gas cylinders, gloves, welding glasses, etc (Figure 4 illustrates the list of 3D tools and instruments).

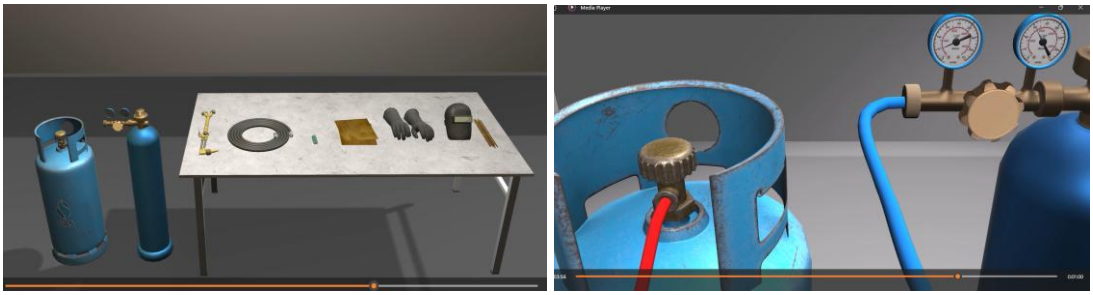


Figure 4: 3D model of tools and 3D instruments

3D models of tools, instruments and components including gas cylinders, regulators, gauges, soldering iron tips, handles, iron blanks...

Next step: Add oxygen and light the fire: use a lighter to light the tip of the soldering iron, the image below illustrates the process of lighting and lighting the fire *(Figure 5)*:

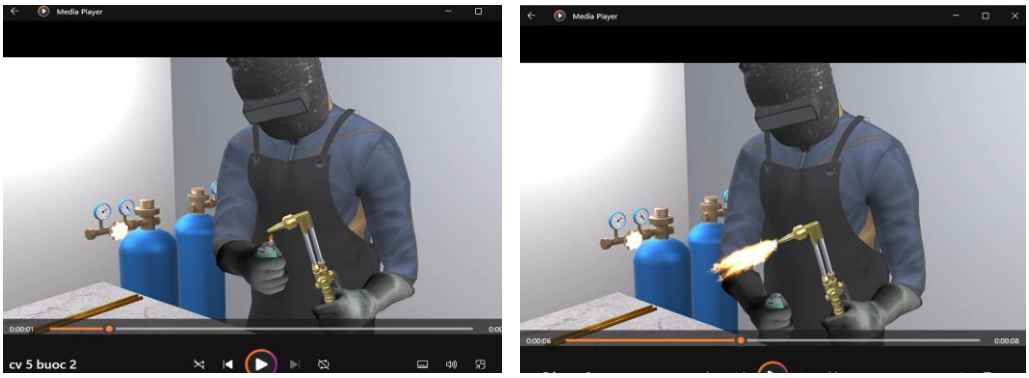


Figure 5: Illustration of adding oxygen and lighting a fire

Final step: Weld the iron billet along the predetermined weld line.

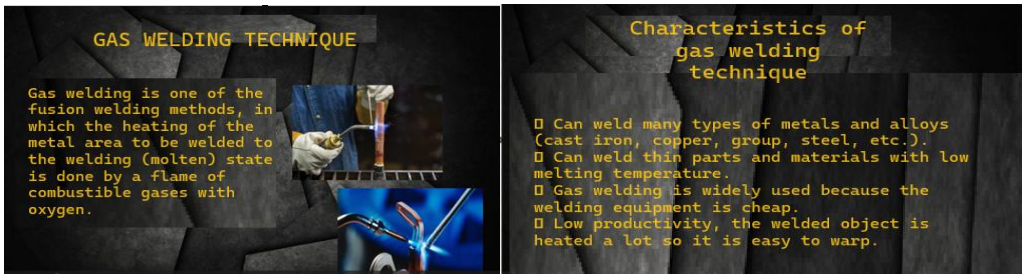


Figure 6: Some initialization and introduction interfaces for metal welding techniques using gas welding techniques

In figure 6, the initialization interfaces of the virtual reality simulation program for welding metal using gas welding technique are illustrated, with introductory information, descriptions of the advantages and disadvantages of the method of welding metal using gas welding technique, tools and equipment that need to be prepared, and an introduction to each welding step with automatic explanations so that the performer can know and understand before performing the welding steps.

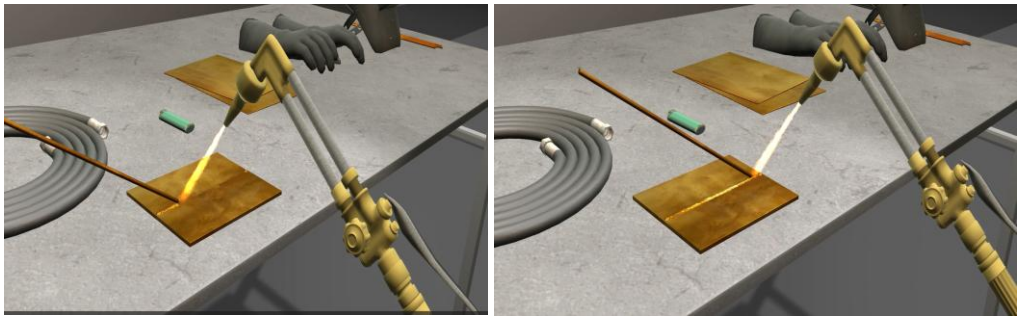


Figure 7: *Illustration of the welding process of two pieces of workpiece together*

In Figure 7, the welding process of two metal plates is illustrated along a predetermined welding path and the welding torch is moved from left to right.

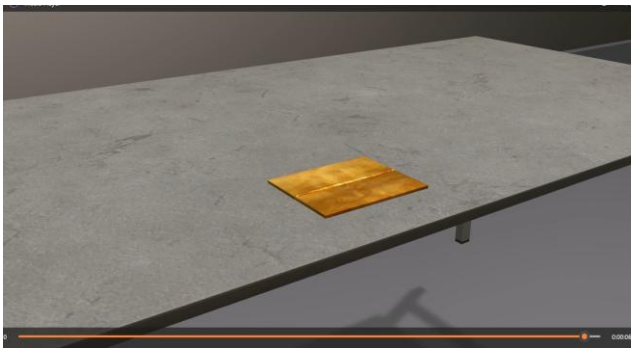


Figure 8: The result of a piece of the workpiece after welding

In Figure 8, the result of a metal plate being joined through the welding method using the gas welding technique is illustrated.

DISCUSSION

Section 4.1 presented the construction of a virtual simulation program for a metal welding practice using gas welding techniques using virtual reality technology to digitally convert traditional practice. The virtual simulation system of the metal welding practice using gas welding technique has been built on the basis of researching the content of the traditional practice, from which multimedia methods such as cameras, scanning... are used to collect tools, instruments and related components used in the practice, building 3D models of each tool and component. On that basis, proceed to design, arrange and assemble to build a virtual practice of metal welding using gas welding technique.

In order to evaluate and test the virtual reality practice on metal welding using gas welding technique, the group of authors built a group of 5 criteria on friendliness, ease of use, model quality, practice instruction scenario, etc. The group of authors designed a survey to distribute and investigate relevant scientists, education experts and learners. Through organizing a scientific seminar, presenting in detail the virtual reality practice software on metal welding using gas welding techniques. Then, conducting a survey. At the seminar, the group of authors invited about 30 experts, scientists, teachers with specialized knowledge related to welding, electrical, mechanical engineering... and 250 students studying from 5 colleges and vocational schools in Thai Nguyen province that provide training in electrical, mechanical, welding...

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 to introduce the main functions guiding the virtual vocational training skills practice of metal welding using gas welding techniques on a simulation software environment. The results were evaluated by 30 experts, scientists, teachers and 250 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 Table 3.

Table 3 *Summary of survey results*

Survey criteria	Expert assessment (%)	Expert assessment not satisfactory	Learner rating (%)	Learner assessment not satisfactory
The interface (friendly, easy to use, easy to understand...)	26(87%)	4	235(94%)	15
The quality of 3D models of tools, instruments and components used	28(93%)	2	235(94%)	15
The practice tutorial script	27(90%)	3	225(90%)	25
The accuracy and ease of understanding of the practice instructions	27(90%)	3	235(94%)	15
The quality, logic of the audio guide to the practice lesson	28(93%)	2	235(94%)	15

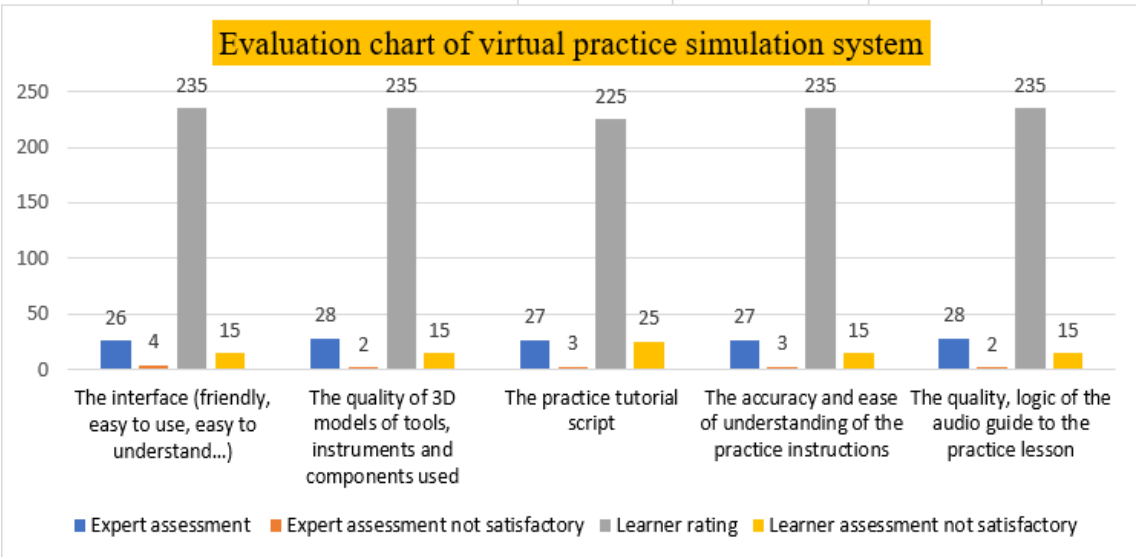


Figure 9: Evaluation chart of virtual reality practice simulation system

Thus, based on the chart in Figure 9, it shows that the virtual reality simulation system for metal welding using gas welding technique ensures the evaluation criteria of quality, interface, teaching scenario... ensuring quality and is highly evaluated. Table 3 also shows the results of the evaluation survey of experts and learners with high evaluation rates of quality such as:

- Regarding the interface (friendly, easy to use, easy to understand...): Up to 87% of experts, scientists and teachers rated it as satisfactory; up to 94% of learners rated it as satisfactory, while the remaining 6% 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 93% of experts, scientists and teachers rated the 3D models as satisfactory; up to 94% of learners rated the 3D models as satisfactory, while the remaining 6% of learners suggested further revisions.

- Regarding the practice instruction script: Up to 90% of experts, scientists and teachers rated the instruction script as satisfactory; up to 90% of learners rated the instruction script as satisfactory, while the remaining 10% of learners rated it as unsatisfactory.

- Regarding the accuracy and ease of understanding of the practice instructions: up to 90% of experts, scientists and teachers assessed that it met the requirements; up to 94% of learners assessed that it met the requirements, while the remaining 6% of learners suggested further revisions.

- Regarding the quality and logic of the audio guide to the practice lesson: Up to 93% of experts, scientists and teachers assessed that it met the requirements; up to 94% of learners assessed that it met the requirements, while the remaining 6% of learners assessed that it did not meet the requirements.

CONCLUSION

In the trend of global digital transformation, the 4th industrial revolution, research and proposal of innovative solutions for training models and methods of practical skills for students in vocational education institutions play an important role, contributing to improving the effectiveness of vocational skills training quickly and effectively for students, meeting the increasing demands of the labor market, the need for high-skilled jobs in society.

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 programming languages such as C#... The article has chosen to pilot the construction of a virtual practice lesson for metal welding using gas welding techniques. The results of the virtual practice test were evaluated by 30 experts, scientists, and teachers currently teaching at vocational training institutions and tested in 6 classes with 250 students asked for their opinions. The evaluation results have been summarized, analyzed and commented on in section 4.2, showing that the virtual simulation system of the metal welding practice using gas welding technique has met the requirements and ensured quality. Through the virtual practice system, learners can grasp knowledge and approach and apply the practice faster, mastering the practical skills of the lesson better.

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