A digital transformation approach from traditional to virtual practice: A case study of gas welding corner-welding

Nguyen Van Huan[1], Nguyen Thi Hang[1*], Nguyen Thi Hue[2]

[1]Thai Nguyen University of Information and Communication Technology, Thai Nguyen City, Thai Nguyen Province, Vietnam
[2]Duc Chinh Primary School, Tue Tinh Commune, Hai Phong City, Vietnam

Received 7 October 2024; revised 23 December 2024; accepted 26 May 2025

Abstract:

The digital transformation context has opened up many new opportunities in the field of education and training, allowing learning to take place in multiple environments with rich experiences. Converting the traditional vocational training model to virtual vocational training will bring many benefits, creating a flexible learning environment, improving knowledge and skills for learners, and reducing training costs. The article focuses on analysing the current situation of vocational training and teaching activities at vocational training institutions in the current period, therefore proposing solutions to digitally transform vocational training models, contributing to improving vocationcal training quality and enhancing competitiveness in the labour market. The article selects a pilot project to build a virtual vocational training model for virtual practice on the metal corner welding method using gas welding techniques. The virtual practice has been tested with 40 experts, scientists, teachers, and 270 students studying at five colleges and vocational secondary schools in Thai Nguyen province (before the administrative merger) that provide training in electricity, mechanics, welding, etc., and the results have shown its effectiveness when digitally transforming traditional professional practice models.

Keywords: **electrical profession, mechanics, practice, virtual reality, virtual vocational training.**

Classification numbers: **3.1, 3.2, 7**

1. Introduction

In the current economic situation, studying a university programme requires a minimum of four years, with a substantial financial cost of hundreds of millions. In fact, the number of high school graduates enrolling in university is decreasing and shifting towards vocational schools. Most vocational training programmes from colleges, intermediate schools, and even short-term vocational training courses require significantly less time and money, making them suitable for most students, especially in economically disadvantaged areas. The challenge with vocational training is ensuring the quality of training meets the needs of learners who, after studying, need to possess solid skills and be ready to work immediately without requiring retraining by businesses. However, if vocational skills are to be trained to a proficient level, investing in equipment, machinery, and materials for vocational training is also very costly, particularly in high-tech manufacturing industries. There is a need for solutions to support vocational training programmes to reduce costs. Even universities that train in technical fields such as mechanics and electronics still lack practical models and modern equipment.

Based on the survey and analysis of the situation of vocational education in our country over the past ten years, the policies and concerns, along with the projects on vocational training, focus on mechanical vocational training, training methods, and generalising the situation of applying science and technology, such as virtual reality (VR) technology, in building design and simulating virtual and remote practical lectures to support the improvement of training quality. Virtual reality is a simulated experience that employs 3D near-eye displays and pose tracking to provide the user with an immersive feel of a virtual world. Applications of virtual reality include entertainment (particularly video games), education (such as

*Corresponding author: Email: nthang@ictu.edu.vn

medical, safety, or military training), and business (such as virtual meetings). Augmented reality (AR) is an interactive experience that combines the real world with computer-generated 3D content. However, through the analysis and evaluation of section 3.4, it is evident that vocational training activities in general, and mechanical vocational training in our country, have not met the quality requirements; equipment and training methods remain limited, and there has been no innovation in training methods. This is one of the reasons why the quality of vocational training has not met the demands of the current labour market.

Thus, in order to obtain an objective assessment of the current status of vocational training support equipment at educational institutions nationwide, it is crucial to research, survey, synthesise, and develop an objective, honest, and accurate report on vocational training support equipment. This will serve as a basis for proposing solutions to innovate current vocational training models and teaching methods. This article will focus on researching, surveying, synthesising, and analysing the current status of vocational training support equipment at a number of vocational training institutions, with a pilot study at vocational training schools in Thai Nguyen province*.

2. Research methods

Because the research objective of the article is to build a virtual practice lesson with practical application, the research method employed is a combination of the following methods:

Document analysis and literature review: The authors use this method to search for and collect documents, books, newspapers, and scientific research works, both domestically and internationally, related to the application of information technology and advanced technologies such as virtual reality and augmented reality, to develop practical solutions and simulate lessons in virtual environments. This includes inheriting the content of outlines, lectures, lesson plans, and practical lesson content from various vocational training institutions.

Field survey: Conducted at a vocational training school in Thai Nguyen city that provides mechanical training, this survey aims to observe and understand the teaching process. Visual survey images serve as the basis for constructing virtual practice models with operations suitable for technical and skill requirements.

Modelling method: Based on collected images of tools, instruments, and equipment used in mechanical, welding, and electrical practice exercises, the research team maps these into graphics software and processes any noise. Subsequently, software tools are employed to create 3D models of tools, instruments, and equipment such as welding machines, welding rods, steel billets, and protective gear. Technical support technologies are utilised to create 3D models of equipment and instruments used in mechanical equipment manufacturing, including 3Ds Max for shaping, ZBrush for detailing and concavity, Substance Painter for material creation, and Maya for movement and animation.

Experimental method: This involves using programming languages and control programming technologies such as C#, Unity 3D graphics library, and OpenGL to install the programme for testing simulations. This means integrating the equipment components and tools of each separate practice into a complete practice scenario. At the same time, the quality of the model and scenario corresponding to each practice is tested and evaluated.

Expert method: Meetings are held with a number of experts, teachers, and scientists with expertise in fields such as mechanical engineering, manufacturing, automation, or information technology training at various educational and training institutions in Thai Nguyen city. These meetings aim to interview and seek comments and advice on how to construct a virtual practice lesson, the steps involved, and the requirements that need to be met. Additionally, opinions and assessments are solicited regarding the quality of the 3D models digitising the equipment and tools used in the mechanical equipment manufacturing practice lesson, as well as the quality of the content of each virtual practice lesson.

3. Research contents

3.1. The need to conduct a digital transformation from traditional practice models to virtual practice models

In the context of the rapid development of digital technology today, the conversion of vocational practice models from traditional to virtual has become extremely important. The application of digital means and virtual

*Before the administrative merger.

vocational practice not only enhances the quality of teaching but also improves the experience of learners. Consequently, most countries worldwide have focused on researching and developing applications of virtual reality technology in building and developing software to simulate lessons and practices in the industry in general and the mechanical industry in particular. As a result, some achievements have been made, demonstrating the need for vocational training institutions in our country, including technical schools, to find solutions to exploit the application of virtual reality technology in designing appropriate, intelligent, and remotely adaptive practice lectures as tools for students and learners across the country, particularly in mountainous and ethnic areas.

Augmented reality technology helps overcome the difficulty of reading technical documents because augmented reality easily creates a link between representation and reality by overlaying virtual components on real devices [1-4]. Augmented reality has proven suitable for assembly operations (saving time), maintenance (reducing human error and task completion time) [5], as well as training. The application of augmented reality enhances interaction within the professional practice environment [5]. Augmented reality is also an effective technology platform for training in the field of mechanics [6, 7], even for practices that require high precision [8], by reducing the required mental workload. D. Scaravetti, et al. (2019) [9] demonstrated that working with an optimised augmented reality system can reduce stress compared to traditional practice systems.

In the context of mechanical engineering education, students often face difficulties in mechanical design, reading engineering plans or 3D models, making connections with real systems, and determining the kinematic chain of a mechanism. A preliminary experiment with students highlighted their interest in augmented reality [10]. Therefore, augmented reality increases motivation and enjoyment of learning, serving as a catalyst for students to explore and visualise complex phenomena [11]. This leads to significant improvements [12]. There are studies that have investigated and used augmented reality in learning, compared to virtual reality, augmented reality enhances the sense of "presence" and improves memorability [13], with performance highlighted by previous studies [14, 15]. Other literature reviews reveal promising trends and identify positive impacts of using augmented reality in education [16-18]; the advantages include increased learner motivation and positive attitudes, improved understanding and performance, heightened learner engagement, superior performance in physical tasks, and enhanced communication and group collaboration.

Currently, augmented reality is being developed by universities [19, 20]; however, no precise studies have been found on the relationship between the functions provided by augmented reality solutions and the need for technical demonstration in mechanical engineering. Therefore, it is essential to analyse these functions to assess the relevance and impact of augmented reality on learning. B. Dumas (2019) [21] emphasised that in the context of using augmented reality as an educational tool, it is essential to apply a technical solution that allows both teachers and learners to build skills relevant to the mechanical engineering profession. Different stakeholders should not be burdened with time-consuming programming or graphics activities. M. Nebeling, et al. (2020) [22] and H. Imottesjo, et al. (2020) [23] utilised CAD technology to represent and display 3D models to support the construction of detailed parts in practical lectures and to describe the detailed operation process.

In the context of engineering education, students encounter difficulties in mechanical design, such as reading technical sketches or 3D models, making connections with real systems, and determining the kinematic chain of a mechanism. Augmented reality solutions support the need for technical cognition or representation in the teaching of mechanical engineering. Using augmented reality technology, mechanical simulations can be easily demonstrated [24-26] using augmented reality in the mechanical profession in 2017 to build a simulation system that helps identify tools taken from a tool cart or to ensure the conformity of an assembly (verifying the presence or location of components). Augmented reality is well suited for the following purposes: gestures are simulated and superimposed directly on the real system on which the operator is working in the correct location. J.S. Ortiz, et al. (2017) [27] studied and proposed a virtual reality system for automotive mechanics training, specifically describing a virtual training system for the identification and assembly of automotive parts. The system includes a virtual reality environment developed with the Unity 3D graphics engine, which allows users to be more immersed in the teaching-learning process, optimising materials, infrastructure, and time resources, among other benefits. The proposed system enables users to choose the working environment and the level of difficulty during training.

Experimental results demonstrate the effectiveness of the system created through the interaction between humans and machines, oriented towards developing skills in the field of automotive mechanics.

Thus, vocational schools are now facing pressure to adapt to new technology trends to meet training needs in the digital world. The digital transformation of vocational practice models at vocational schools will create a more flexible and convenient learning environment for students. Virtual practice allows students to access courses and materials anytime, anywhere, through internet-connected devices, providing them with the flexibility to self-study and practice skills without having to attend school. This is not only a necessary step but also an opportunity to improve the quality of education and training, increase convenience, and save costs. To be successful, vocational schools need to continue investing in technology and human resource development while creating a safe, flexible, and engaging learning environment.

3.2. Current status of virtual reality technology application in vocational training activities

In developed countries such as the US, the UK, Germany, and France, training activities and education streams have focused on the development of vocational engineers. These nations have paid attention to, researched, exploited, and applied advancements in products to enhance practice in the field of smart vocational training, thereby constructing practice modules and practical lectures associated with advanced technologies in practice and experiments [28]. Consequently, the industries in these countries have developed remarkably and are at the forefront of the world, particularly in the mechanical sector [29, 30]. These countries have researched and developed applications of virtual reality and augmented reality technology to build software and smart practice modules that support the simulation of all practice lessons, experiments, and implementation processes in a visual and interactive manner within virtual space, akin to real space. Through this system, students can master the work of mechanics or any other profession [31], thereby contributing to the enhancement of training quality and the formation of a team of highly skilled workers upon graduation.

The research on the application of virtual reality technology techniques to the construction of virtual practice lessons for mechanical engineering, in particular, and other professions, in general, has garnered interest from many managers and scientists, achieving significant results. D. Scaravetti, et al. (2021) [32] provided a general analysis of augmented reality in the context of industry and higher education, detailing the process of determining augmented reality scenarios with technical constraints and focusing on research regarding its use and demand in mechanical engineering. They argued that the global industry is at the centre of the fourth industrial revolution, driven by the emergence of new digital solutions, particularly augmented reality. This technology is currently underutilised in higher education, especially for mechanical engineers. The application of virtual reality and augmented reality technologies will foster learning and develop learner autonomy. Simultaneously, the study assesses the relevance of augmented reality in the current context and its impact on training. The difficulties students face when approaching an engineering system are related to reading and understanding 2D and even 3D representations, a lack of knowledge about the functions of components, and the analysis of power transmission chains and motion conversion. The study has identified the relevance of augmented reality technology to teaching effectiveness and increasing the accessibility of knowledge for beginners. Other studies have presented augmented reality scenarios developed on various mechanical systems, utilising the relevant features of the augmented reality interface [33]. Furthermore, these experiences have allowed for the identification of specific problems related to augmented reality implementation. The choice of augmented reality devices and software facilitates a digital thread that integrates with the digital tools and files used by mechanical engineers [34]. Ultimately, the studies aim to evaluate how this technology can help learners overcome difficulties in different learning situations.

The use of virtual reality and augmented reality is a crucial aspect of developing professional skills adapted to the technological context that engineers must navigate. Since 2013, virtual reality and augmented reality have evolved from new technologies to practical teaching tools [35, 36]. Moreover, virtual reality and augmented reality represent educational technologies with significant advancements [37]. In 2018, there were studies indicating that more than 600 companies utilised augmented reality, finding it has superior potential and relevance compared to virtual reality [38]. The description of the augmented reality application model is presented in Fig. 1.

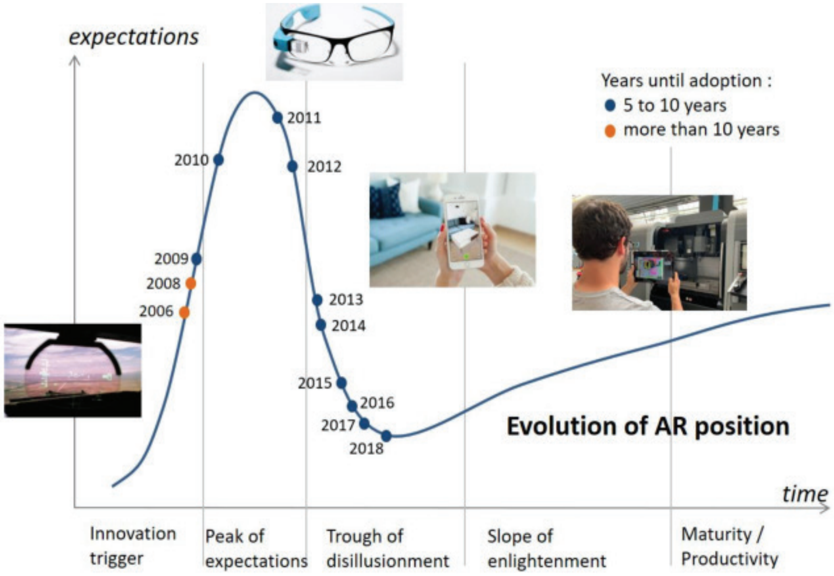

Fig. 1. Augmented reality application model [38].

In Vietnam, numerous research projects have been undertaken by scientists, educators, and managers interested in studying the application of technology to develop virtual practice lessons that support the teaching and training of various professions [39]. For example, the project "Virtual experiments and chemical experiments" led by Associate Professor Dr. Nguyen Duc Chuy from Hanoi National University of Education and his colleagues, utilised cameras to record real chemical experiments (as per the script) and subsequently converted the video signals into movie files that can be run on computers. The project "Scientific research and development of information and communication technology", coded KC-01-14, led by Associate Professor Dr. Vu Trong Sy and his colleagues, successfully developed software featuring 20 virtual experiments to facilitate the teaching of Physics 8 and 9, Chemistry 9, and Biology 8 and 9. The project "Virtual general physics laboratory", developed by the Institute of Technical Physics at Hanoi University of Science and Technology, employs virtual physics experiment software. This software fully designs the liquids, gases, and equipment used, ensuring the authenticity of the scientific processes and simulating experimental operations "almost" as they occur in reality, thereby creating a virtual practice and experimentation environment that closely resembles real life as displayed on the computer [40, 41].

Currently, many domestic educational institutions, ranging from vocational education to colleges and universities, as well as managers, scientists, and businesses, have shown interest in researching, developing, and implementing various solutions to transform the vocational training model. This transformation aims to shift from purely theoretical teaching and training or traditional practice equipment to virtual, smart, and remote vocational practice models by employing advanced technology, 4.0 technology, or virtual reality technology to design and build virtual practice software [42-44]. In particular, according to the leaders of some training schools, virtual practice not only adapts to the unpredictable developments of the COVID-19 pandemic but also represents a means of 'taking a shortcut' in the digitalisation of vocational training [44]. Virtual welding, virtual car repair, and other applications on virtual reality devices or modern software are being utilised by many vocational schools. With practical training accounting for 60-70% of the training programme, vocational and secondary schools have recently faced significant challenges due to the COVID-19 pandemic, which has interrupted practical training as students have been unable to attend school.

Thus, the current state of mechanical engineering training in vocational institutions nationwide is still lacking in practical equipment. These institutions have not yet fully exploited or kept pace with the applications of advanced science and technology, digital transformation, and the outcomes of the fourth industrial revolution, such as virtual reality and augmented reality, in developing virtual and smart mechanical practice training solutions [45, 46]. This shortfall has resulted in a decline in the number of students and individuals participating in mechanical vocational training, leading to a decrease in quality, whereby learners do not meet the skills required upon graduation from training courses.

3.3. Proposed solutions to convert traditional vocational practice models into virtual vocational practice

Virtual practice enables vocational schools to create online learning platforms featuring interactive materials, lectures, and exercises, thereby assisting students in understanding and applying knowledge more effectively. Advanced technologies such as 3D images, virtual reality, and interactive experiences provide students with opportunities to learn interactively and practice in a safe and realistic environment. Consequently, it is essential to enhance the application of virtual reality technology in the digital transformation of virtual practice models. Online classes also foster an interactive and engaging learning environment. Rather than merely sitting and listening to lectures from teachers, students can participate in interactive activities such as online discussions, educational games, and online assessments. This approach allows them to engage with knowledge in a more active and stimulating manner, thereby improving their comprehension and retention. As a result, online classroom solutions and virtual reality simulation systems are becoming increasingly popular and necessary in modern education. Smart classroom solutions and virtual reality simulation systems support human resource training in the automotive, welding, health, and pharmaceutical industries, with applications designed to provide interactive, hands-on learning experiences. In the era of Industry 4.0, education is undergoing significant innovation with the emergence of online classrooms and virtual reality simulation systems. This solution not only offers new learning experiences but also enhances the quality of education and training.

For this solution to be effective, vocational schools must establish a robust technology platform to support the implementation of virtual reality courses and simulations. This includes developing specialised applications and software, as well as building network infrastructure to ensure stable and fast internet connections. Additionally, vocational schools need to enhance and promote the development of training content, such as constructing online courses or virtual reality simulations. This content should be designed to reflect practical skills and knowledge pertinent to specific professions while being engaging and appealing to attract students' interest. Training and support for teachers to effectively utilise new technologies and develop high-quality educational content also play a crucial role. Educators need guidance on how to interact with students in online and virtual reality environments to optimise the learning process. One of the significant advantages of online learning and virtual reality is the ability to create an interactive and enjoyable learning environment. Therefore, it is essential to design interactive learning activities, such as online discussions, educational games, and online assessments, to stimulate student interest and interaction, while ensuring accessibility and the effective implementation of virtual reality simulation courses. This includes providing internet access and learning devices to all students and creating financial support policies for those from disadvantaged backgrounds. It is also necessary to design effective measurement and evaluation methods to ensure that online courses and virtual reality simulations achieve the desired learning outcomes. This may involve the use of online assessments, feedback from students, and monitoring their progress over time. For each learning module, specific simulations are required; for instance, when teaching mechanical engineering, simulation systems should create opportunities for learners to explore mechanical components through a variety of 3D simulation objects, thereby developing the fundamental principles needed in various manufacturing processes, including production, logistics, and maintenance.

Pilot project to build a virtual vocational training model for virtual practice on metal corner welding method using gas welding:

In this article, the authors investigate, test, and develop a virtual practice for the metal corner welding method employing gas welding techniques. Building upon traditional lessons, the authors establish a pilot process for metal corner welding using gas welding techniques, facilitated by virtual reality technology, as follows:

Details of the welding process steps:

Step 1: Prepare the tools and equipment required for the metal corner welding method using gas welding techniques, including gas cylinders, gas flow control valves, gas lines, metal pieces, welding rods, a welding torch, and protective gear such as gloves, helmets, and clothing.

Step 2: Create 3D models of the tools and instruments using software applications such as 3DS Max and Unity 3D.

Step 3: Execute procedures with the gas cylinder, including opening the cylinder, unscrewing the gas cylinder lock, and adjusting the gas cylinder gauges to meet the required specifications.

Step 4: Ignite the flame and adjust the steam or gas pressure.

Step 5: Welding process: first, heat the welding billet, insert the welding tip into the joint to be welded, and simultaneously introduce the welding rod into the weld. The welding rod should be moved from left to right across the area to be welded.

Step 6: Heat the copper until it melts into the weld to achieve the desired welding result.

Based on the above six steps for the method of welding metal corners using gas welding techniques, the project team proceeded to develop a virtual practice using virtual reality technology and other technologies, including:

There are numerous 3D modelling tools available worldwide. However, in this article, the authors utilise 3Ds Max and Unity 3D, as these are two convenient, user-friendly, and easy-to-use tools for creating 3D models while providing high-quality outputs (illustrated in the results of building 3D models of tools and equipment at the following link: https://daphuongtien.io.vn/detaicapbo/). Moreover, these two tools support exporting to various 3D model formats and can easily generate simulation videos of practical exercises. ZBrush is employed for creating shapes and convexities, Substance Painter is used for developing materials, and Maya is utilised for creating movement and animation.

The programming technology group responsible for building virtual, interactive practice lessons includes C#, the Unity 3D Engine, and VRML. These technologies are used to programme the control of initialising (loading) 3D models into the virtual reality environment, as well as to programme the control of camera settings, interaction with 3D tools, and the steps of the virtual practice process.

The flowchart of the virtual practice building process is shown in Fig. 2.

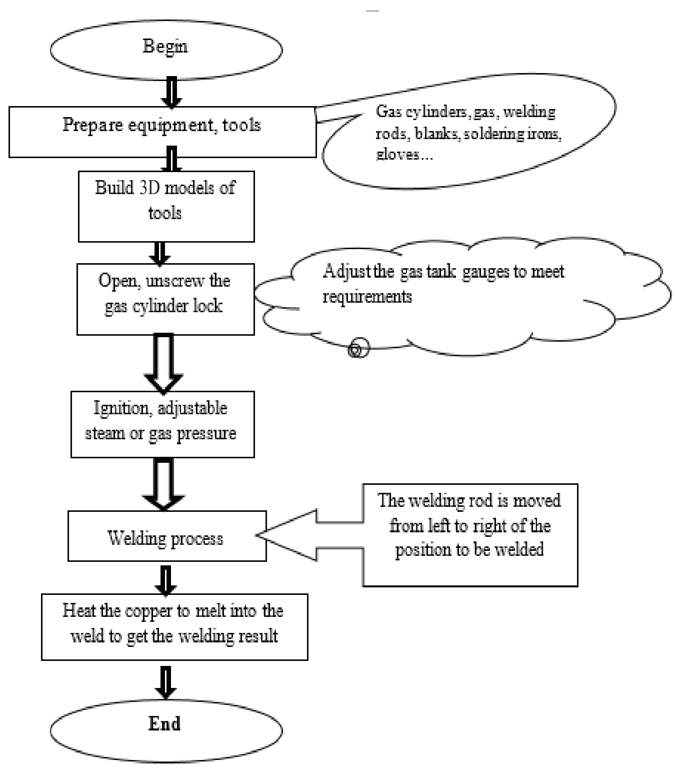

Fig. 2. Flowchart of the virtual practice building process. Source: Compiled by the authors.

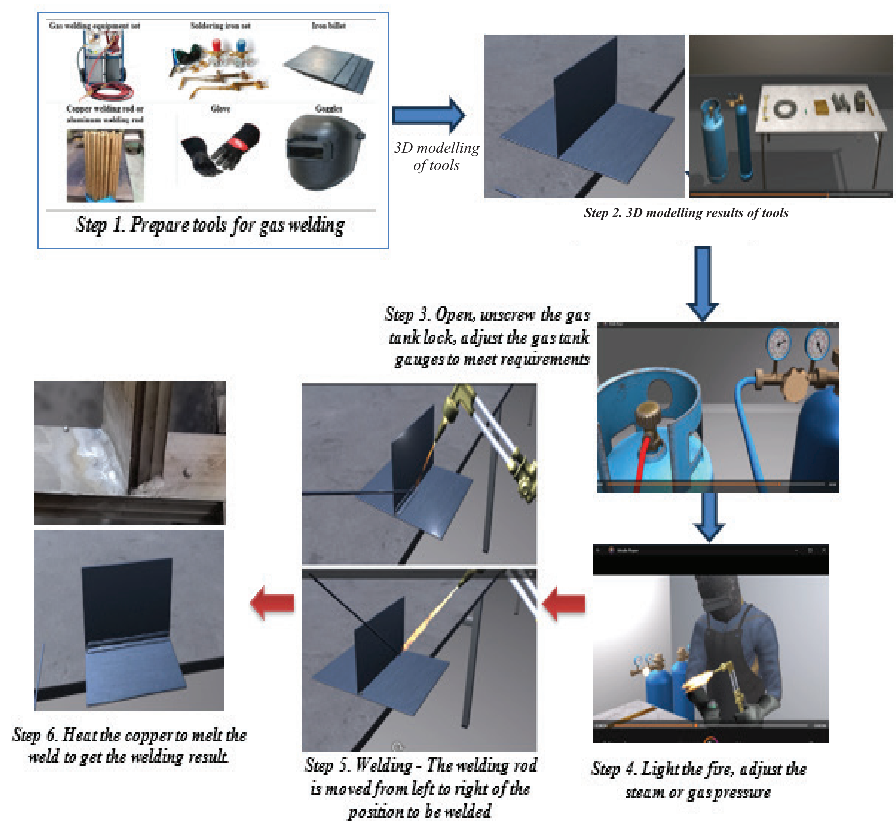

Fig. 3. Results of each step in building a practical model of metal welding using gas welding techniques. Source: Compiled by the authors.

Figure 3 illustrates each step in building a virtual practice model from preparation to final result. The instructions for preparing the necessary tools, equipment, and components used in the practice, as well as determining cutting lines and connecting/adjusting gas cylinders are provided under each image.

Fig. 4. Tools, instruments, and components used in the practice. Source: Compiled by the authors.

Figure 4 shows all the tools, equipment, and components used in practice, which include a gas cylinder, regulator, gauge, soldering iron tip, handle, and iron billet.

Figures 5 and 6 are illustrations of the iron billet, gas cylinder valve, igniting the soldering iron, and the welding process.

3.4. Evaluation of virtual simulation programme for practical practice of fillet welding technique using gas welding

Section 3.3 above presented the construction of a virtual simulation programme for a gas welding corner-welding practice lesson, developed based on research into the content of a traditional practice lesson. Multimedia methods, such as cameras and scanning, were employed to collect tools, instruments, and related components used in the practice lesson, facilitating the creation of a 3D model for each tool and component. Building upon this foundation, the design,

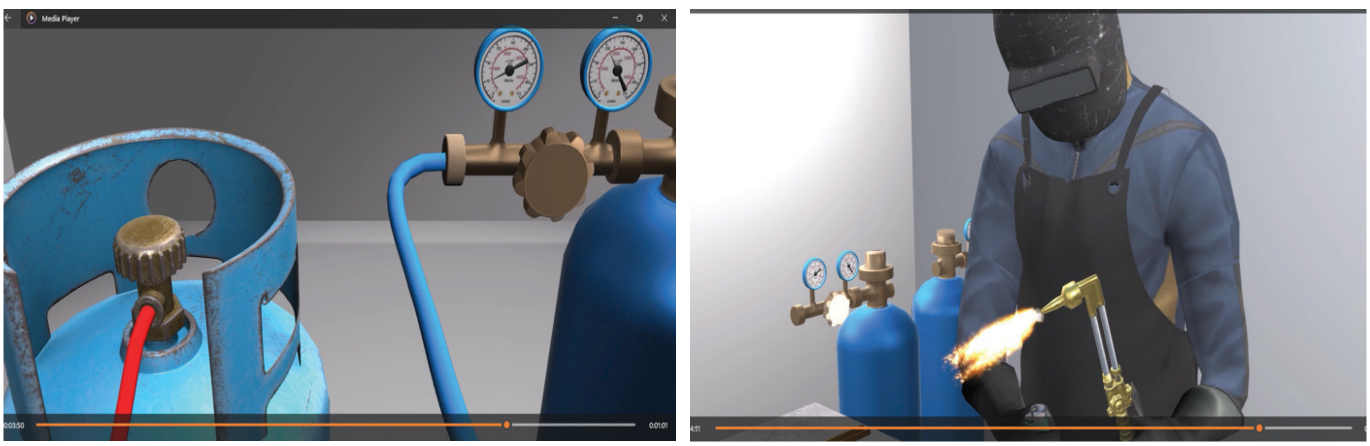

Fig. 5. Illustration of gas cylinder valve and soldering iron ignition. Source: Compiled by the authors.

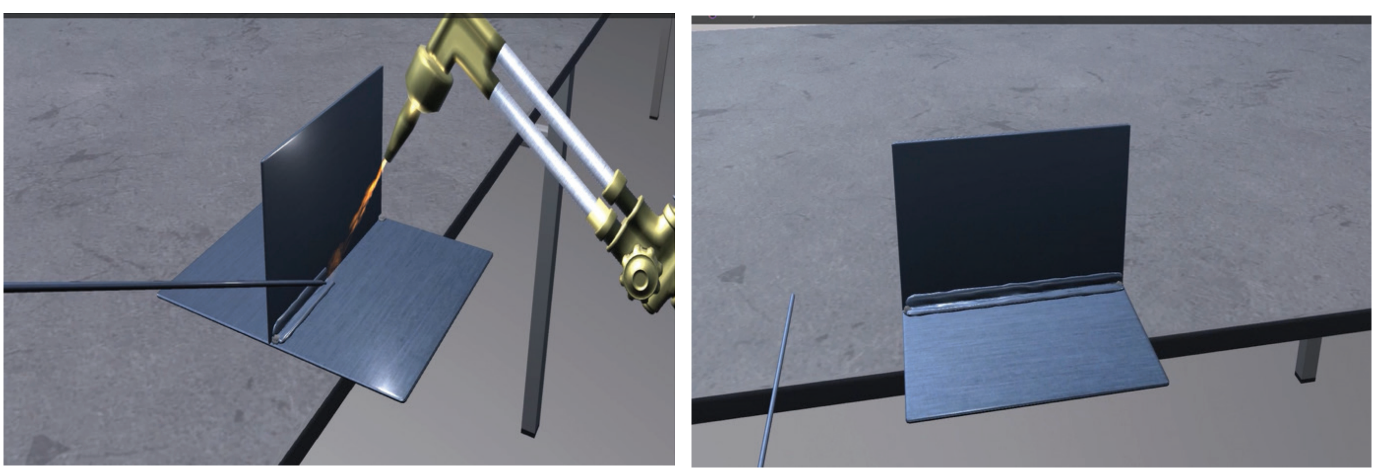

Fig. 6. Illustration of welding process and welding results. Source: Compiled by the authors.

arrangement, and assembly of a virtual gas welding corner-welding practice lesson were carried out.

To evaluate the quality and convenience of the virtual simulation system for the practical welding of corner pieces using the gas welding method, the article assessed the system by organising a scientific workshop and inviting approximately 40 experts, scientists, and teachers with specialised knowledge related to welding, electrical engineering, and mechanical engineering, as well as 270 students from five colleges and vocational schools in Thai Nguyen province that offer training in electrical, mechanical, and welding disciplines.

The scientific workshop focused on presenting two main topics: an overview of the content of the traditional practical lesson teaching script and a demonstration of the programme introducing the main functions guiding the virtual vocational training skills practice lesson on corner welding using the gas welding method within a simulation software environment. The results received evaluations from 40 experts, scientists, and teachers, as well as 270 students from five colleges and vocational secondary schools in Thai Nguyen province that provide training in electricity, mechanics, welding, and related fields (Table 1). The evaluation results and comments are as follows:

Table 1. Summary of survey results.

Survey criteria	Expert assessment achieved	Expert assessment not satisfactory	Learner assessment achieved	Learner assessment not satisfactory
About the interface (friendly, easy to use, easy to understand...)	34 (85%)	6	250 (93%)	20
About the quality of 3D models of tools, instruments and components used	38 (95%)	2	249 (92%)	21
About the practice tutorial script	37 (93%)	3	260 (96%)	10
About the accuracy and ease of understanding of the practice instructions	33 (83%)	7	248 (92%)	22
About the quality, logic of the audio guide to the practice lesson	37 (93%)	3	244 (90%)	26

Source: Compiled by the authors.

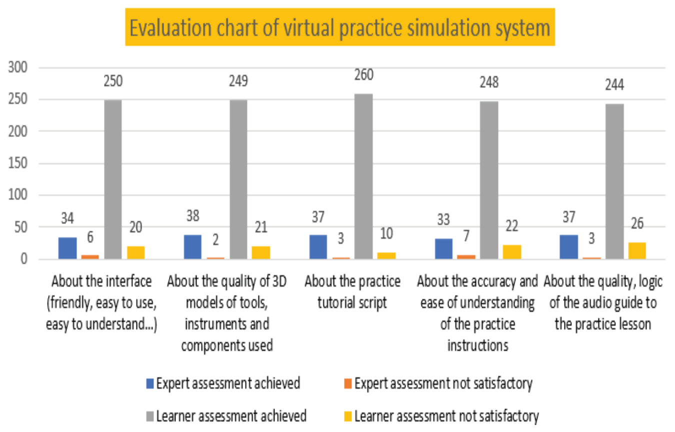

Fig. 7. Evaluation chart of virtual practice simulation system. Source: Compiled by the authors.

Based on Fig. 7, the following observations can be made:

Regarding the interface (friendly, easy to use, easy to understand): up to 85% of experts, scientists, and teachers rated it as satisfactory; up to 93% of learners rated it as satisfactory, with the remaining 7% suggesting adjustments to enhance user-friendliness.

Regarding the quality of the 3D models of tools, instruments, and components used in the practice: up to 95% of experts, scientists, and teachers rated the 3D models as satisfactory; up to 92% of learners rated them as satisfactory, with the remaining 8% recommending further improvements.

Regarding the practice instruction script: up to 93% of experts, scientists, and teachers rated the instruction script as satisfactory; up to 96% of learners rated it as satisfactory, while the remaining 4% rated it as unsatisfactory.

Regarding the accuracy and ease of understanding of the practice instructions: up to 83% of experts, scientists, and teachers assessed that it met the requirements; up to 92% of learners agreed, with the remaining 8% suggesting further revisions.

Regarding the quality and coherence of the audio explanation of the practice instructions: up to 93% of experts, scientists, and teachers assessed that it met the requirements; up to 90% of learners concurred, while the remaining 10% considered it inadequate.

The pilot application implemented at vocational training institutions in Thai Nguyen has demonstrated significant results. The details are presented in Table 2.

Table 2. The effectiveness of vocational training activities at educational institutions in Thai Nguyen province before and after implementing the virtual reality vocational training digital-transformation model.

Vocational training facility	Current status of practical guidance before applying virtual reality technology into practice (Source: Actual survey at school from learners at link: *https://forms.gle/d4KNtt7ZJvtqYXZh9*)	Effectiveness of applying virtual reality technology to support virtual reality practice in vocational training (Source: The authors; Virtual practice software - *https://daphuongtien.io.vn/detaicapbo*)
Thai Nguyen College of Economics and Techniques	Not yet 100% met, learners mainly use old equipment; Virtual reality technology has not been applied	100% of learners can practice virtually on the software. Learners can practice anytime, anywhere. Save time and investment costs.
Vietnam-Germany Industrial College	Not yet 100% met, learners mainly use old equipment; Virtual reality technology has not been applied	100% of learners can practice virtually on the software. Learners can practice anytime, anywhere. Save time and investment costs.
College of Technology and Commerce	Not yet 100% met, learners mainly use old equipment; Virtual reality technology has not been applied	100% of learners can practice virtually on the software. Learners can practice anytime, anywhere. Save time and investment costs.
Thai Nguyen Industrial College	Not yet 100% met, learners mainly use old equipment; Virtual reality technology has not been applied	100% of learners can practice virtually on the software. Learners can practice anytime, anywhere. Save time and investment costs.
Thai Nguyen Vocational School	Not yet 100% met, learners mainly use old equipment; Virtual reality technology has not been applied	100% of learners can practice virtually on the software. Learners can practice anytime, anywhere. Save time and investment costs.

Source: Compiled by the authors.

The research findings presented in this article hold significant implications for innovating teaching methods and enhancing the quality of practical skills training in vocational lessons for students and learners. Consequently, this approach enables learners to practise proficiently using vocational virtual reality simulation software. It provides learners with access to virtual digital equipment based on virtual reality technology, allowing for convenient practice without constraints of space and time, thereby facilitating practice anytime and anywhere. Therefore, the proposed solution demonstrates practical significance by reducing investment costs.

4. Conclusions

To support practical training, a more effective solution is required, namely the development of virtual practice models. Through these virtual practice models, learners interact within a simulated environment closely resembling reality, enabling them to experience and practise vocational skills comparable to those in a real setting. Learners can access documents, knowledge, equipment, and working processes via a virtual interface, and engage in exercises, simulations, and interactions with virtual elements. They can carefully observe virtual reality videos, study sample operations to understand the technical movements of experts, and practise basic movements independently without equipment. Subsequently, learners can practise on technical equipment; for example, driving lessons have begun implementing this method, allowing learners to train in virtual cabins. Thus, training facilities can easily increase practice time for learners while reducing costs. If students are passionate about their profession and capable of self-study, they will develop highly effective practical skills. Furthermore, this solution enhances learners' interest in practising and testing within the virtual reality system. Simultaneously, the virtual practice model helps to mitigate risks during the training process. Moreover, it allows learners to experience diverse situations and scenarios without geographical or physical constraints, providing a safe environment while facilitating the detection and correction of errors and mistakes. This supports learners in improving their skills and confidence before performing practical operations on equipment in real environments. Vocational skill training at vocational training institutions today plays a crucial role in creating a substantial labour force for the country, contributing to the development of production, the economy, and social security. In recent years, although the state has prioritised vocational training with specific and clear orientations and goals, significant achievements have been realised, altering the allocation of labour resources nationwide and generating wealth for society.

In the future, the authors intend to continue improving the software interface and the functions of vocational practice guidance, enhancing the quality of lecture explanations. They also plan to add and update other vocational skill practice lessons in alignment with current trends to train vocational skills for students and learners across the country.

CRediT author statement

Nguyen Van Huan: Conceptualisation, Methods, Writing overview of research situation, Writing and Running virtual practice models; Nguyen Thi Hang: Survey, Analysing and Processing data, Writing conclusions; Nguyen Thi Hue: Editing, Proofreading, Translation, Document search support, Document synthesis.

ACKNOWLEDGEMENTS

This article is a product of the 2024 ministerial-level project "Research on developing a practical model of teaching smart mechanical engineering based on the application of virtual reality techniques for students in mountainous and ethnic minority areas", code: B2024-TNA-05.

COMPETING INTERESTS

The authors declare that there is no conflict of interest regarding the publication of this article.

REFERENCES

[1] V.H. Nguyen, D.T. Vu, V.T. Nguyen, et al. (2006), *Real World Simulation Programming Techniques Based on 3D Morphit*, Hanoi Science and Technology Publishing House, 183pp (in Vietnamese).

[2] G. Reinhart, C. Patron (2003), "Integrating augmented reality in the assembly domain-fundamentals, benefits and applications", *CIRP Annals-Manufacturing Technology*, **52(1)**, pp.5-8, DOI: 10.1016/S0007-8506(07)60517-4.

[3] V.D. Lehner, T.A. DeFanti (1997), "Distributed virtual reality: Supporting remote collaboration in vehicle design", *IEEE Computer Graphics and Applications*, **17(2)**, pp.13-17.

[4] S. Borsci, G. Lawson, S. Broome (2015), "Empirical evidence, evaluation criteria and challenges for the effectiveness of virtual and mixed reality tools for training operators of car service maintenance", *Computers in Industry*, **67**, pp.17-26, DOI: 10.1016/j.compind.2014.12.002.

[5] M. Wang, V. Callaghan, J. Bernhardt, et al. (2018), "Augmented reality in education and training: Pedagogical approaches and illustrative case studies", *J. Ambient. Intell. Humaniz. Comput.*, **9**, pp.1391-1402, DOI: 10.1007/s12652-017-0547-8.

[6] S. Webel, U. Bockholt, T. Engelke, et al. (2011), "Augmented reality training for assembly and maintenance skills", *Proceedings of The BIO Web of Conferences*, DOI: 10.1051/bioconf/20110100097.

[7] S. Webel, B. Uli, T. Engelke, et al. (2013), "An augmented reality training platform for assembly and maintenance skills", *Robot. Auton. Syst.*, **61(4)**, pp.398-403, DOI: 10.1016/j.robot.2012.09.013.

[8] N. Gavish, T. Gutiérrez, S. Webel, et al. (2015), "Evaluating virtual reality and augmented reality training for industrial maintenance and assembly tasks", *Interact. Learn. Environ.*, **23(6)**, pp.778-798, DOI: 10.1080/10494820.2013.815221.

[9] D. Scaravetti, D. Doroszewski (2019), "Augmented reality experiment in higher education, for complex system appropriation in mechanical design", *Proceedings of The CIRP Design Conference*, pp.197-202, DOI: 10.1016/j.procir.2019.04.284.

[10] G. Cooper, H. Park, Z. Nasr, et al. (2019), "Using virtual reality in the classroom: Preservice teacher's perceptions of its use as a teaching and learning tool", *Educ. Media Int.*, **56(1)**, pp.1-13, DOI: 10.1080/09523987.2019.1583461.

[11] A. George (2015), "Lockheed is using these augmented reality glasses to build fighter jets", *Pop. Mech.*.

[12] U. Neumann, A. Majoros (1998), "Cognitive, performance, and systems issues for augmented reality applications in manufacturing and maintenance", *Proceedings of The IEEE Virtual Reality Annual International Symposium*, pp.4-11, DOI: 10.1109/VRAIS.1998.658416.

[13] H. Liou, S. Yang, Y. Chen, et al. (2017), "The influences of the 2D image-based augmented reality and virtual reality on student learning", *J. Educ. Soc.*, **20(3)**, pp.110-121.

[14] B. Kenwright (2018), "Virtual reality: Ethical challenges and dangers", *IEEE Technol. Soc. Mag.*, **37(4)**, pp.20-25, DOI: 10.1109/MTS.2018.2876104.

[15] I. Radu (2014), "Augmented reality in education: A meta-review and crossmedia analysis", *Pers. Ubiquitous Comput.*, **18(6)**, pp.1533-1543, DOI: 10.1007/s00779-013-0747-y.

[16] M. Akçayır, G. Akçayır (2017), "Advantages and challenges associated with augmented reality for education: A systematic review of the literature", *Educ. Res. Rev.*, **20**, pp.1-11, DOI: 10.1016/j.edurev.2016.11.002.

[17] P. Chen, X. Liu, W. Cheng, et al. (2017), "A review of using augmented reality in education from 2011 to 2016", *Innovations in Smart Learning*, pp.13-18, DOI: 10.1007/978-981-10-2419-1_2.

[18] M. Sirakaya, D.A. Sirakaya (2018), "Trends in educational augmented reality studies: A systematic review", *Malays. Online J. Educ.*, **6(2)**, pp.60-74, DOI: 10.17220/mojet.2018.02.005.

[19] Y. Yuliia, V. Tkachuk, T. Hruntova, et al. (2019), "Augmented reality in training engineering students: Teaching methods", *Proceedings of The CEUR Workshop Proceedings*, pp.952-959.

[20] P. Milgram, F. Kishino (1994), "A taxonomy of mixed reality visual displays", *IEICE Trans. Inf. Syst.*, **77(12)**, pp.1321-1329.

[21] B. Dumas (2019), "Augmented reality: Information in the right place, at the right time", *Proceedings of The TEDx Université de Namur Conference*, https://cds.unamur.be/docs/videos/tedx/dumas, accessed 20 October 2024.

[22] M. Nebeling, K. Lewis, Y. Chang, et al. (2020), "XRDirector: A role-based collaborative immersive authoring system", *Proceedings of The CHI Conference on Human Factors in Computing Systems*, pp.1-12, DOI: 10.1145/3313831.3376637.

[23] H. Imottesjo, L. Thuvander, M. Billger, et al. (2020), "Iterative prototyping of urban cobuilder: Tracking methods and user interface of an outdoor mobile augmented reality tool for co-designing", *Multimodal Technol. Interact.*, **4(2)**, pp.1-21, DOI: 10.3390/mti4020026.

[24] E. Demitriadou, K.E. Stavroulia, A. Lanitis (2020), "Comparative evaluation of virtual and augmented reality for teaching mathematics in primary education", *Educ. Inf. Technol.*, **25(1)**, pp.381-401, DOI: 10.1007/s10639-019-09973-5.

[25] M.E. Fiorentino, A. Uva, G. Monno, et al. (2012), "Augmented technical drawings: A novel technique for natural interactive visualization of computer-aided design models", *J. Comput. Inf. Sci. Eng.*, **12(2)**, DOI: 10.1115/1.4006431.

[26] A. MacAllister, M. Hoover, S. Gilbert, et al. (2017), "Comparing visual assembly aids for augmented reality work instructions", *Proceedings of The Mechanical Engineering Conference Iowa State University*, 16pp.

[27] J.S. Ortiz, J.S. Sánchez, P.M. Velasco, et al. (2017), "Teaching-learning process through VR applied to automotive engineering", *Proceedings of The 9th International Conference on Education Technology and Computers*, pp.36-40, DOI: 10.1145/3175536.3175580.

[28] D. Nguyen (2021), "Application of VR/AR/MR virtual reality technology in current industries", https://onetech.vn/blog/ung-dung-cong-nghe-vr-ar-mr-cho-cac-nganh-nghe-13548, accessed 20 October 2024 (in Vietnamese).

[29] D.G. Ullman (2010), *The Mechanical Design Process*, New York: McGraw-Hill, 433pp.

[30] V.H. Andaluz, J.S. Sánchez, J.I. Chamba, et al. (2016), "Unity3D virtual animation of robots with coupled and uncoupled mechanism", *International Conference on Augmented Reality, Virtual Reality and Computer Graphics*, Springer International Publishing, pp.89-101, DOI: 10.1007/978-3-319-40621-3_6.

[31] R.T. Azuma (1997), "A survey of augmented reality", *Presence: Teleoperators and Virtual Environments*, **6(4)**, pp.355-385.

[32] D. Scaravetti, R. François (2021), "Implementation of augmented reality in a mechanical engineering training context", *Computers*, **10(12)**, DOI: 10.3390/ computers10120163.

[33] J. O'Heir (2021), "Future ready with digital skills", *The American Society of Mechanical Engineers*, https://www.asme.org/topics-resources/content/future-ready-with-digital-skills, accessed 20 October 2024.

[34] A. Nandan (2020), "Best software courses for mechanical engineering students", *Skyfi Education Labs*, https://www.skyfilabs.com/blog/best-software-courses-for-mechanical-engineering-students, accessed 20 October 2024.

[35] H.B. Lisboa, L.A.R.O. Santos, E.R. Miyashiro, et al. (2013), "3D virtual environments for manufacturing automation", *Brazil 22nd International Congress of Mechanical Engineering (COBEM 2013)*, pp.559-567.

[36] I. Farkhatdinov, J.H. Ryu (2009), "Development of educational system for automotive engineering based on augmented reality", *International Conference on Engineering Education and Research*, 6pp.

[37] L. Duh, E. Klopfer (2013), "Augmented reality learning: New learning paradigm in co-space", *Comput. Educ.*, **68**, pp.534-535, DOI: 10.1016/j.compedu.2013.07.030.

[38] L. Cohen, P. Duboé, J. Buvat, et al. (2018), "Augmented and virtual reality in operations: A guide for investment", *Capgemini Research Institute*, 34pp.

[39] M. Quyen (2021), "When vocational students practice virtually", https://thanhnien.vn/khi-sinh-vien-truong-nghe-thuc-hanh-ao-1851042351.htm, accessed 10 October 2024 (in Vietnamese).

[40] D.A. Tran (2008), *Virtual Practice Experiments - Applications in Mechanical Vocational Training*, Master's thesis, Hanoi University of Science and Technology (in Vietnamese).

[41] L.K. Nguyen (2009), *Development and Utilization of Virtual Laboratory Experiments in Vocational Training*, Master's Thesis, Hanoi University of Science and Technology Technology (in Vietnamese).

[42] T.T.H. Vu, N.S. Pham, M.D. Nguyen, et al. (2024), "The current state of virtual reality and augmented reality adoption in Vietnamese education: A teacher's perspective on teaching natural sciences", *International Journal of Information and Education Technology*, **14(3)**, pp.476-485, DOI: 10.18178/ijiet.2024.14.3.2068.

[43] H.H. Le (2005), *Experiments, Virtual Practice Applied in Teaching Industrial Engineering Grade 12*, PhD Thesis, Hanoi National University of Education, accessed 20 January 2024 (in Vietnamese).

[44] T.N. Le (2001), *Applying Simulation Methods to Teaching Industrial Engineering*, PhD Thesis, Hanoi National University of Education, accessed 20 February 2024 (in Vietnamese).

[45] VR Solutions (2024), "Virtual reality simulation technology equipment and solutions", http://www.vrsolutions.vn, accessed 10 October 2024.

[46] P.M. Hung (2023), "Virtual reality applications in vocational training technology in vietnam and the world", *International Journal of Advances in Engineering and Management*, **5(1)**, pp.67-72.