Investigation and Evaulation of a Virtual Reality Vocational Training System for General Lathe

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Abstract: The purpose of this study is to explore the effects of virtual reality (VR) vocational training content for lathe skills and to evaluate usability. A lathe is one of the most basic and important machines for conducting various mechanical operations including cutting, drilling, sanding, knurling, etc. Therefore, it is necessary to consider practice and repetition as a method for acquiring the skill to operate a lathe machine. How to further increase operation skill must also be addressed. Opportunities to repeatedly practice using a lathe are very limited in actual educational environments due to the expense of equipment and the risk of machine operation. In order to overcome these limitations, we have developed a VR lathe training system and evaluated its usability and effectiveness by working with vocational training teachers. As a result, similarity with an actual practice environment was confirmed, and the outlook for using this VR solution in classes is high. Furthermore, the teachers involved provided feedback to further improve the VR training system developed.

1 INTRODUCTION

The introduction of technology to education has increased both efficiency and effectiveness of traditional learning methods. For instance, use of ICT technology in education enables learning resources to be shared as well as facilitating cooperative learning. Furthermore, use of ICT in education not only provides tools for improving projects and enabling learning based on real problems, but also introduces new curricula that can provide more feedback to both teachers and students, changing the education and training environment (Bhattacharjee, Deb, 2016). Recently, experience-oriented educational content that actively engages learners has been expanding. To construct experience-oriented educational content, advanced technology such as virtual and augmented reality has been used in educational media.

Virtual reality (VR) technology has been evolving since its use for US military combat training simulations in the 1970s, and recently, its usage has further expanded to include games, entertainment, education and other industries (Lee, et al., 2018). In recent years, VR technology has become more personalized and interactive due to the evolution of computer hardware and rendering technology. VR technology focuses on providing an immersive experience by offering a virtual space even more realistic than the real world or by constructing an imaginary new world (Martín-Gutiérrez, et al., 2017). Immersion is a key feature of VR technology and is associated with interactivity and visual presence (Rosemblum, Cross, 1997). Through VR, a user interacts with many virtual objects and experiences the same real feelings as being in the physical world (Bae, Noh, 2014).

VR technology can be applied to education and used as a tool to have students solve problems occurring in the real world through simulations, or it can be used to stimulate a learner’s interest and promote voluntary learning motivation and participation in learning (Freina, Ott, 2015). In the future, if the media characteristics of VR are considered sufficiently and content is differentiated from the existing image media continuously, there is a high possibility that the utilization of VR in educational institutions and work experience fields

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will further expand. This is because VR offers access to areas such as the human body or outer space that cannot be directly experienced; this also applies for topics accompanied by great cost or risk, such as scientific experiments, military training, and medical practice, all of which can be experienced under controlled circumstances through VR simulation (So, 2016). Therefore, the future of VR is very promising.

In general, the novelty of new technology in education increases learning effects by attracting learners' interest and attention (Jang, Kye, 2007). VR technology is expected to contribute as an educational medium beyond merely offering a novel effect, improving effectiveness and efficiency for behavior-oriented learning, practical education, and self-directed experience. In this respect, VR technology is most suitable for vocational training that emphasizes practical field experience, practical training, and scenarios that are too difficult or dangerous to construct in reality. In these contexts, VR allows users to experience safe, low-cost technical training without expensive machines or devices. Accordingly, the Ministry of Employment and Labor in Korea has been developing and distributing VR vocational training content for technical vocational training fields. Thirty-five kinds of realistic virtual training content have been developed by KOREATECH. KOREATECH provides free VR content (machinery, electricity & electronics, environmental, energy, safety and construction, etc.) to both public and private vocational training institutions and high schools for vocational education and training. By providing this content at no charge to public sectors, it is possible to avoid budget duplications for purchasing training equipment when carrying out different types of vocational training in the same field. It also helps develop the content available at educational institutions. Furthermore, it increases the utilization of VR training content.

KOREATECH has a total of 35 virtual training modules (as of May 2018). Among these, the course for learning to use a lathe offers skills for one of the most basic machines in the field of manufacturing. So, this can be considered a basic training course, universally required for vocational training in the technical engineering field (Park, 2013). The purpose of this study is to discuss the necessity of a VR vocational training system for vocational training and education teachers in Korea. In Section 2, we describe the overall structure of the VR system developed, and in Section 3, we present usability evaluation results. In Section 4, we discuss the necessity of developing and disseminating VR content in vocational training.

Table 1: VR/AR Vocational training content list (KOREATECH).

Field	VR Vocational Training Content
Machinery (11)	Turbo chiller, Hybrid vehicle, Screw-type chiller system, Clean-diesel engine vehicle, General purpose milling machine, Absorption Refrigeration Systems, Machining center ORIGIN setup (Establishment of a reference coordinate system), Maintenance training for absorption chiller-heater, Maintenance training for thermal power plant boiler main equipment, **General-Purpose Lathe**, Motor vehicle chassis maintenance training: Steering device, Braking device
Electricity & electronics (15)	Hydraulic proportional control training device, Control and operation & maintenance in clean room, Wind power generator, SMT in line system Installation and operation & maintenance of photovoltaic power generator, Hydraulic elements design, Practice of piping wiring work
Chemistry (1)	Chemical Handling Laboratory Safety Experience
Construction (2)	Overhead crane safety content, Container crane safety content
Architecture (5)	Passive house design, Construction of reinforced concrete buildings, Landscape architecture, Forklift operator test, Total station and GNSS
Materials engineering (1)	Shielded metal arc welding training

2 SYSTEM COMPOSITION OF THE VR LATHE MACHINE

The suggested VR vocational system is composed of a base station, a head mounted display (HMD), a VR controller, and a PC. Figure 1 shows a block diagram of the proposed system. The base station continues to emit an infrared laser (IR laser) after the power is turned on. When a user holds the VR controller and moves it, the resulting motion is measured by a sensor consisting of an inertia measurement unit (IMU) and an IR photo detector. The IMU measures the rotational motion of the VR controller, and the IR photo detector receives the IR laser to compute the linear motion of the VR controller. The measured translation/rotation motion is conveyed to the PC to represent interactions with a virtual environment via a wireless communication module. The motion analyzer receives human motion commands and interprets them. According to the interpreted human motion, target virtual objects are manipulated and operated. The amount of interaction corresponds to vibration commands conveyed to the VR controller to drive the vibration motor. Furthermore, the virtual environment is displayed by the HMD according to the amount of interaction. Therefore, a user not only visually watches stereoscopic images through the HMD but also feels haptic sensations via the VR controller.

Most virtual objects for the vocational content are modeled with 3D max, and tiny objects are captured with a 3D scanner. We applied widely-accepted UV texture mapping to virtual objects to increase the level of immersion. Figure 2(a) shows a wireframe model of the virtual lathe developed, and Figure 2(b) shows it displayed as a solid. Figure 2(c) shows the model with a texture applied. In this study, we positioned and rendered the textured model in a virtual environment using Unity3D to construct immersive VR content.

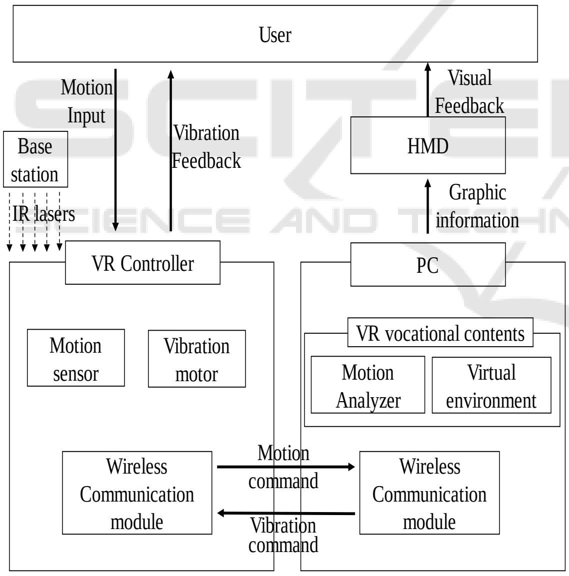

Figure 1: Block diagram of the proposed system.

In order to efficiently manage the virtual objects in the VR content, objects were divided into avatars, dynamic objects, and static objects. The VR controller and stationary objects such as backgrounds were defined as avatars and static objects, respectively. A target device/machine that a user wants to learn is defined as a dynamic object. A user touches dynamic objects with a VR controller to activate or operate them. Manipulation of a dynamic object takes place only after a collision between the user's avatar and the object occurs. A simple proxy was used to efficiently detect collisions between avatars and a target object. In constructing a virtual environment, data management is separated from visualization. This separation allows a user to easily modify virtual target objects without unintended effects. If VR vocational content is started by a user, a virtual environment including a target device and working hand tools is automatically loaded with a main menu.

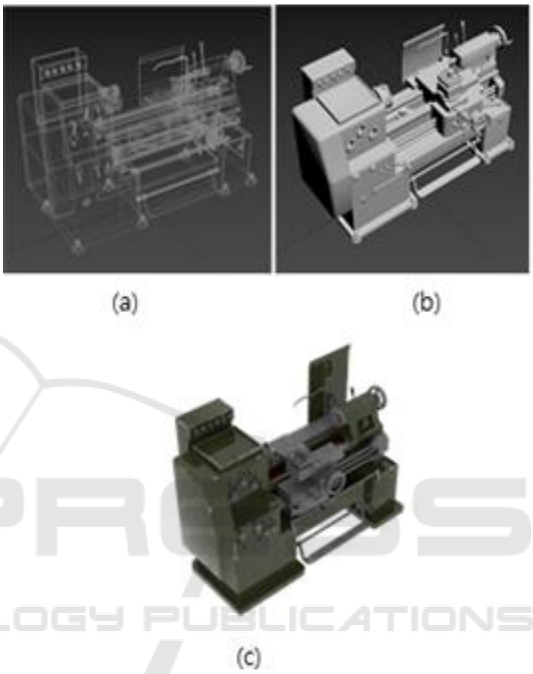

Figure 2: Target object, (a) wireframe model, (b) solid model, and (c) textured model (model after texture is applied).

The virtual lathe content developed includes two modes: a learning and practice mode. In learning mode, a user studies the basic concept of the lathe including its operation principle and its parts. Furthermore, the user learns how to operate handwheels (cross-feed and carriage handwheels), levers (cross-feed and half-nut levers), and dials. In addition, the user comes to understand how to control operation speed, etc., with the virtual lathe content. For practice mode, we have prepared some manufacturing processes. Figure 3 shows a manufacturing process example. A user selects a material and plans a process; then, he/she manipulates wheels, levers, and spindles to control the speed of the headstock or material to be moved.

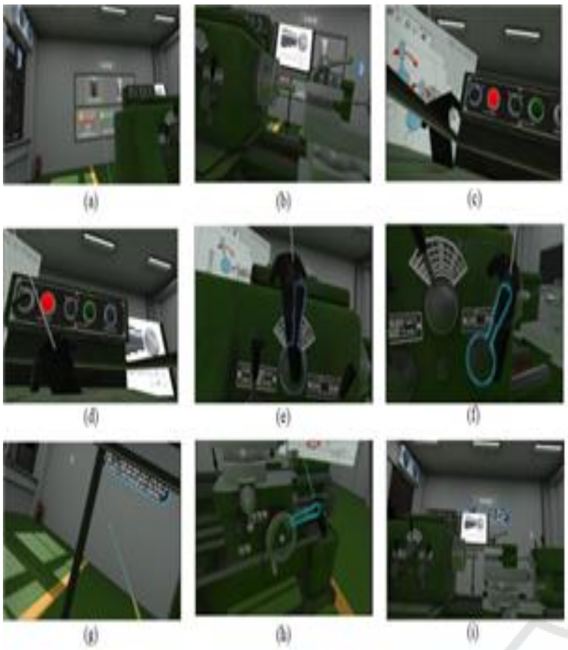

Figure 3: Example of a manufacturing process.

3 RESULTS

3.1 Methods

To develop usability testing criteria for our VR lathe content for training teachers, the following was carried out: the development of leading indicators, correction by experts according to the scenario, and the development of core indicators. To achieve this, a draft questionnaire was developed through a literature review (Ryu, J. H., Yu, S. B., 2017; Yu, 2017; So, 2016) and then revised by a team of researchers.

Figure 4: Example of a manufacturing process.

A usability evaluation was then conducted. A total of 8 participants joined this VR lathe content evaluation, and all were male vocational high school training teachers. Due to the limited scope of training teachers who participated in summer job training, few candidate pools were available for testing. Most participants′ ages were 50-60 (50%) or 30-40 (25%). More than half of the participants had a bachelor's degree and they have twenty-seven years of lecture experience(37.5%). None of the participants had experienced VR educational content before. However, 37.5% of them had experience with fragmentary or corresponding vocational training content.

3.2 Satisfaction

Through this study, we investigated overall user satisfaction with the VR content developed, analyzed the usability of VR media, and evaluated the efficiency of VR content. The evaluation response items included wholly dissatisfied (1 point), dissatisfied (2 points), neither satisfied nor dissatisfied (3 points), satisfied (4 points), and wholly satisfied (5 points) according to the Likert 5-point scale.

3.2.1 Overall Satisfaction

Table 2: Overall learning satisfaction.

Content	M	SD
Overall satisfactory in class	3.9	0.99
Likely to be useful for field application	4.1	0.83
I would recommend it to others	3.9	0.83
I am willing to learn other kinds of virtual reality content	4.1	0.99
I expect more classes using virtual reality	4.3	0.71
I am willing to use virtual reality content in the future	4.3	0.88
Total	4.1	0.95

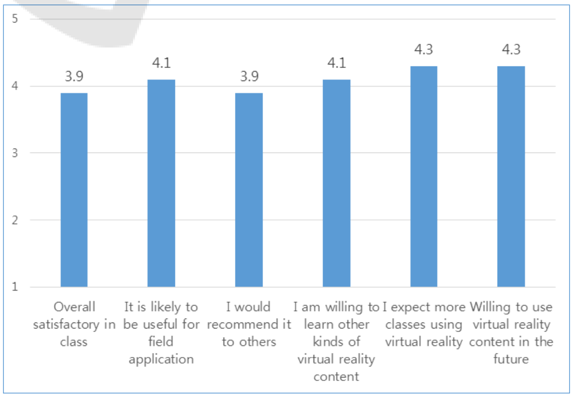

Figure 5: Overall learning satisfaction.

The overall satisfaction score showed an average of 4.1, so users were relatively satisfied. In addition to lathe processing, responses for applying VR to other content in the curriculum and using VR content in the future were highest, indicating that the teachers had a high degree of interest in VR and willingness to use it.

3.2.2 User Convenience and Efficiency as a Teaching Media

We investigated the user convenience of the VR content developed (Table 3 and Figure 6) and its effectiveness as a teaching medium (Table 4 and Figure 7). At first, user satisfaction for convenience was not as high as expected. This may have been caused by the structure of the virtual content, but inexperience with device manipulation in general seems to have been a major factor when considering the main object of investigation for users in their 50-60s. Nevertheless, the strong response indicating users want to utilize VR technology in future classes implies high interest in development possibilities and utilization of VR technology regardless of the present degree of convenience.

Table 3: User convenience.

Content	M	SD
Is user operation easy and convenient?	3.38	1.68
Is the expression and start-up effect of equipment appropriate?	3.25	1.28
Have appropriate sound and equipment effects been used?	3.5	1.19
Was the graphic representation clear?	3.25	0.70
Is the meaning of the information provided correctly understood?	3.62	0.91
Was it easy to control detailed operations during use?	3.5	0.92
Total	3.42	1.11

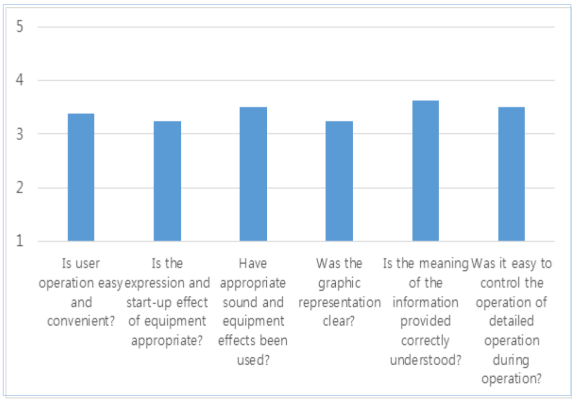

Figure 6: User convenience.

Table 4: Efficiency as a teaching media.

Content	M	SD
I want to use content that utilizes virtual reality in my class.	4.25	3.88
I think virtual reality is appropriate as an educational medium for class.	3.88	0.83
Total	4.06	0.85

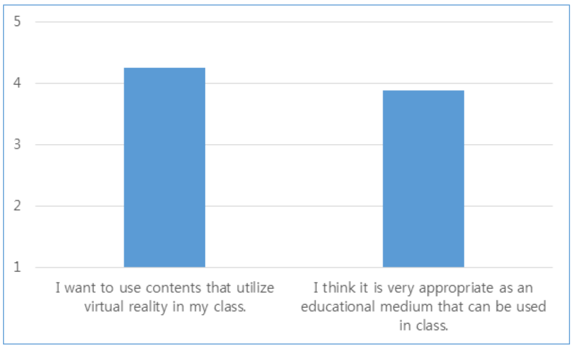

Figure 7: Efficiency as a teaching media.

3.3 Other Comments

In the last stage of usability evaluation, teachers suggested improvements for the VR lathe processing training content. As mentioned above, the level of VR content implementation available to teachers is rather weak now, but nevertheless, they believe that VR content can be developed further in the future. The teachers involved pointed out specific problems with content usage, but if these aspects were improved, they would use our VR lathe processing content.

"This content seems to be very suitable for beginner safety education, operation method explanations and so on."

"It seems necessary to improve precision operation. If this is improved, it is likely to be used in actual classes."

"I want operation to be smoother. I would like the buttons to be fine-tuned."

"I hope you can modify the model to the desired dimensions."

"You should set the work piece size, select several bytes, and fix it on the tool stand."

"When I set the number of revolutions, I wish I could watch the number increase and see the coolant coming out."

"Segmentation is needed to practice step by step."

4 DISCUSSION

In general, the educational goal of technical training is to acquire specific skills or techniques through repetitive learning. Techniques often refer to proficiency in dealing with specific equipment; the smooth use of equipment and machines is an important educational goal. In this paper, VR vocational training content that offers a way to practice smoothly in a low-cost, safe educational environment was presented, proposing educational content with great potential. On the other hand, since VR content may affect learners' ethics, it is necessary to minimize the gap between VR and traditional learners. In addition, we need to discuss how to adapt the role of educators according to effective technology use.

We will need to further refine usability and construct more diverse and clear indicators for usability evaluation in the future. In addition, we will increase the number of survey samples and will systematically investigate the effectiveness, efficiency, and satisfaction of VR vocational training content.

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