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Original Paper

Development of VR curriculum for marine engines

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Abstract: There is an increasing need for education and training on marine engine maintenance in order to prevent marine accidents caused by engine damage. In reality, practical education is difficult to achieve owing to the size and location of the equipment. In light of recent advances in virtual reality (VR) technology, VR educational equipment for marine engines has also been developed. However, there is no curriculum utilizing VR educational equipment for marine engines. Therefore, this study develops an optimized curriculum to utilize VR educational equipment. Accordingly, four main content items were selected, and a detailed content and curriculum was developed as the primary content. The developed curriculum includes content that maximizes the use of VR educational equipment to enhance educational effect. The developed VR curriculum was applied to provide marine engine education to sophomores of Korea Maritime University, and although the sample size was limited, the educational effect was confirmed. If the VR education curriculum is applied to regular curriculum in the future, the maintenance capability of the marine engine can be improved through various practical education programs in a safe environment.

Keywords: Virtual reality, Marine engine, Education and training. Curriculum, Development

1. Introduction

As illustrated in **Figure 1**, the number of marine accidents owing to engine damage has been increasing since 2016. Therefore, the necessity to strengthen education and training to prevent marine accidents, especially engine accidents, is steadily increasing.

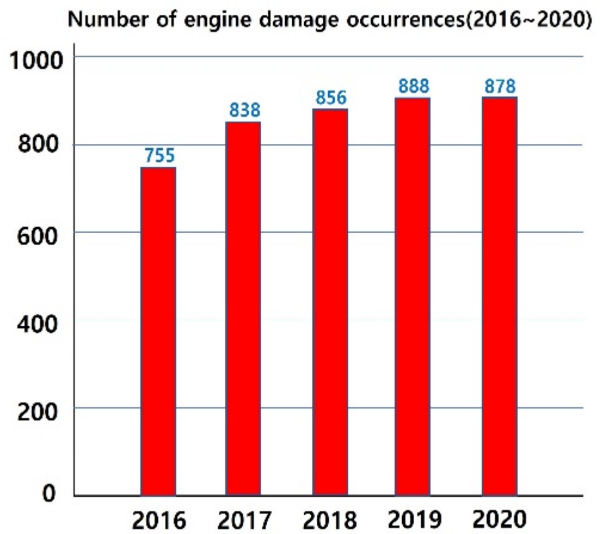

Figure 1: Number of engine damage accidents
(Source: Korean Maritime Safety Tribunal, 2020**[1]**)

However, owing to the size and location of the equipment, practical education with actual equipment is difficult to achieve, so most was based on a sit-down class with photos and videos.

The rapid development of computer, network systems, and program development technologies recently has revolutionized the advancement of educational equipment.

Typical examples are virtual reality (VR) and augmented reality (AR) equipment. The programs and equipment used for traditional games are now being used in education.

In the education sector, VR/AR coding education and framework education were studied for coding education of students in elementary and secondary education sites **[2]**. In the industrial sector, a study was conducted on VR experience safety education to improve the safety of construction sites **[3]**. In the public sector, research examined the development of VR-based educational culture programs for residents in areas that were far from public libraries **[4]**.

As suggested above, educational equipment and programs using VR are being developed in various fields, including the maritime sector.

In general, a study on the development of a VR technology-based remote mental health management program was attempted

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[5] to ensure the crew's mental health in long-term voyages. In the education sector, not only the development of a VR-based marine plant educational system **[6]**, but also a study on the effectiveness of VR experience education for maritime safety was conducted to verify its educational effect **[7]**. In addition, a study to prove the effectiveness of training for safe work in confined areas using VR technology **[8]** and a study to verify the improvement in educational efficiency of ship fire drills through VR compared to actual training were also conducted **[9]**.

Since VR equipment has been actively introduced in marine education, efforts are being made for developing VR-based marine engine equipment **[10]**. VR educational equipment for a large two-stroke diesel engine has recently been developed and installed on the education site.

As shown in **Figure 2**, although VR educational equipment for a large two-stroke diesel engine has been developed and installed, it has yet to be used in practical education and is being utilized only for experiential or special lecture type education.

Figure 2: 2-Stroke Diesel Engine VR Equipment

This is because only the hardware, the VR educational equipment for marine engines, was developed, and not the software that can operate it in the curriculum. Therefore, this study aims to develop an educational curriculum that is necessary to effectively use VR educational equipment for marine engines in the educational field. By developing such education and training curriculum, it will be possible to effectively understand the structure and characteristics of a large two-stroke diesel engine by operating it in the three-dimensional space of VR educational equipment. In addition, it is expected that the developed scenarios can be applied to carry out the education on engine operation, and so on.

2. VR Educational Equipment

2.1 Model engine

Manufacturers of large marine engines include Man Energy Solution (MAN-ES) and WinGD. Considering the importance of education content, market share, and the latest technology, 6S50ME-C engine of MAN-ES was selected as the basic reference engine model as presented in **Table 1**. By operating the engine, the students will effectively understand the structure and characteristics. In addition, it is expected that the developed scenarios can be applied to carry out the education on engine operation, and so on.

Table 1: Ship engine market status of MAN-ES

MAN-ES 2-Stroke Engine world share	About 70%
6S50ME Number of installations	1,193

(Source: MAN-ES)

2.2 VR program

It is important to build a program that makes students feel they are in the actual field with marine engines when wearing VR gears. Therefore, a VR program was created based on the basic data of the selected engine. The developed VR educational equipment is illustrated in **Figure 3**.

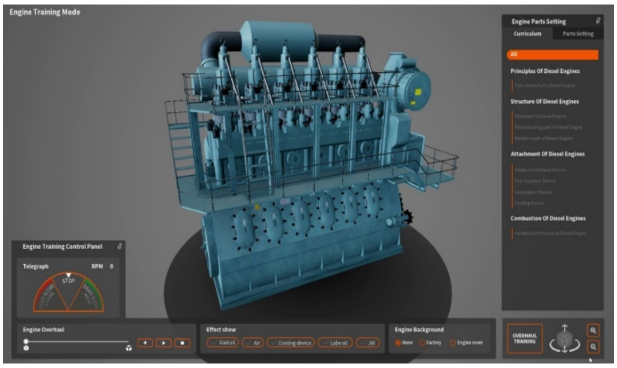

Figure 3: Complete main engine 3D model screen

It was developed using specialized VR programs such as Unity Engine, Maya, SteamVR, and Mixed Reality Portal. In addition, it is equipped with the technology to synchronize the input data to the VR equipment in real time and the rendering engine program optimization technology to provide an immersive feeling of a real engine.

2.3 VR equipment

The hardware specifications of the VR equipment for marine engine education and training are illustrated in **Table 2**.

Table 2: Ship engine market status of MAN-ES

Hardware	Specification
Operating system	Microsoft Window 10

CPU	Intel i7 4770 3.4GHz or above
RAM	Higher than 16GB
SSD	Higher than 256GB
VGA	GTX 1080 recommended
Network	Higher than 100/1,000Mbit
HMD	Oculus

It is configured to provide education and training after the instructor launches the VR program installed on the computer and the students wear the head mounted display (HMD).

3. VR Curriculum Development

3.1 Education Functions of VR Program

The first is the start and stop of engine and the speed increase and decrease function, which can be achieved through the mouse on the on-screen control console. As illustrated in **Figure 4**, the engine simulation created in 3D starts and stops like a real engine through VR, and the RPM can also be changed. To enhance the presence of the field, colors and sounds used in the marine engine have been added. A function to generate a name by clicking on the marine engine accessories was also included.

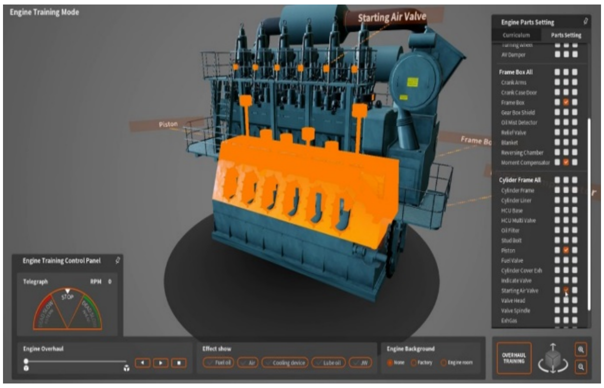

Figure 4: Color and name function

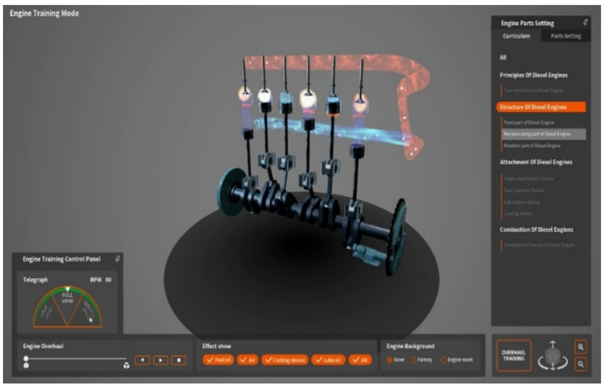

Figure 5: Transparency and fluid flow function

The second is a transparency function for the engine and its accessories as shown in **Figure 5**. If necessary, the piston movement and operation process of valves can be checked. Moreover, the fluid flow of fuel oil and the gas flow of swamp gas are displayed, and the process of being discharged as exhaust gas after combustion in the cylinder is displayed in colors to enhance the educational effect.

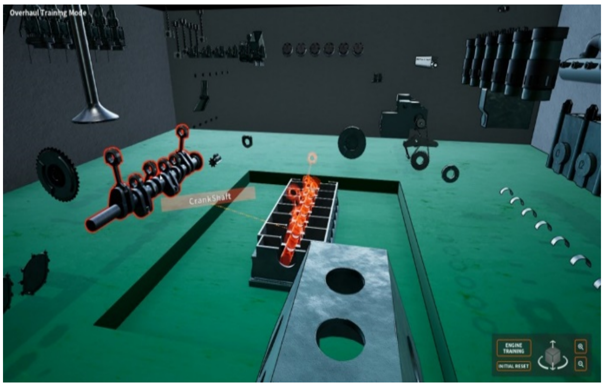

Figure 6: Assembly and disassembly function.

The third function implements the assembly and disassembly process from the bed plate to the cylinder head of a 2-stroke diesel engine, as illustrated in **Figure 6**. This can be conducted as a test in the form of a game.

The fourth function allows multiple participation, of up to four people simultaneously. Through this, the instructor can conduct a lecture to students in virtual reality and students can perform tasks in collaboration.

Figure 7: Internal observation function.

The fifth function is to enter the marine engine in operation, as shown in **Figure 7**, and check the accessories and its operation status. Although this cannot be performed in reality, since it is a simulation, it is possible, and can provide a better understanding of the mechanism of engine operation.

The sixth is a function where a virtual P-V graph is drawn according to the piston position next to the marine engine simulation shown in Figure 8. However, it is not yet possible to realize the physical change of pressure–volume, and it is at the level of realizing the general pressure–volume change that appears as the piston moves between cylinders.

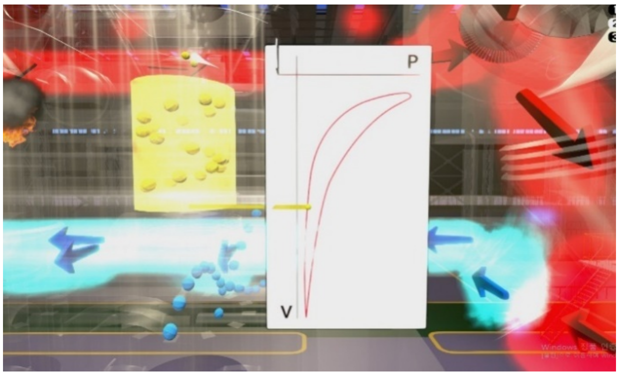

Figure 8: P-V graph function

3.2 VR curriculum content

1) Principle of Diesel Engines

Table 3 summarizes the diesel engine principle implemented by VR contents.

Table 3: Diesel Engine Principle

Content Elements	VR curriculum
2 stroke cycle diesel engine	Diesel Cycle (P-V diagram) implementation and principal explanation.
	Cylinder state implementation and principle explanation(intake→ compression→explosion → exhaust).

2) Structure of Diesel Engines

Table 4 summarizes the diesel engine structure implemented by VR contents.

Table 4: Diesel engine structure

Content Elements	VR curriculum
Fixed part of diesel engine	Indication of the position and name of the main parts, such as cylinder, cylinder liner, cylinder block, and cylinder head, and description of functions.
	Main Bearing and Thrust Bearing position and name indication and function description.
	Description of movement and operation inside the cylinder.
Reciprocating part of diesel engine	The position, name, and function description of the main parts of the piston, piston ring, piston pin, connecting rod, piston rod, and crosshead.
Rotary motion part of diesel engine	Indicate the location and name of the crankshaft and flywheel, which are major parts, and explain their functions.
	Movement of position inside the crank chamber and description of its operation.

3) Accessories of Diesel Engines

Diesel engine accessories implemented by VR contents are summarized in **Table 5**.

Table 5: Diesel engine accessories

Content Elements	VR curriculum
Scavenging/ Exhaust Device	Indicate the location and name of Scavenging pot(in the cylinder liner), the exhaust valve and the piston head, and explain the function.
	Represents and describes the scavenging air flow in the cylinder from turbocharge.
	After the explosion process, the exhaust gas flows through the exhaust valve to the turbocharge and describes.
Fuel oil injection device	Shows and explains the process of fuel injection through the fuel injection valve.
	Indicates and explains the fuel oil flow to the fuel injection valve.
Lubrication device	Indicate the supply of cylinder lubricating oil to the reciprocating part and explain the principle.
	Indicate the system lubricating oil circulation in the rotary motion part and explain the principle.
Cooling device	Indicate the supply of Jacket Cooling Water and explain the principle.
	Description of piston cooling, cylinder cooling.
Turbocharging devices	Shows the internal structure of the turbocharger and explains how it works.
	Indicates and explains the flow of exhaust gas and scavenge air during turbocharger operation.

4) Combustion of Diesel Engines

Table 6 summarizes the diesel engine combustion process implemented by VR contents.

Table 6: Combustion of diesel engines

Content Elements	VR curriculum
Diesel engine combustion process	Using the PV diagram, indicate and explain the injection timing, ignition delay period, explosion combustion period, controlled combustion period, etc.

4. Development Effects and Considerations

4.1 Application of curriculum

A pilot education was conducted to confirm the educational effect and understanding of the developed curriculum. The purpose and method were explained in detail to 50 students, who were divided into two groups of 25 each. As shown in **Table 7**, the participants were sophomores of Korea Maritime University who are receiving maritime education.

Table 7: Trainee introduction

School	Korea Maritime University
Grade	Sophomores
Number of people	50 people
Division	Group A and B(Each 25 people)
Etc	Completion of basic sea level training

To analyze the educational effect as shown in **Figure 9**, in the first stage, both groups of students were seated to acquire basic knowledge about the two-stroke diesel engine.

Figure 9: VR Lecture Scene

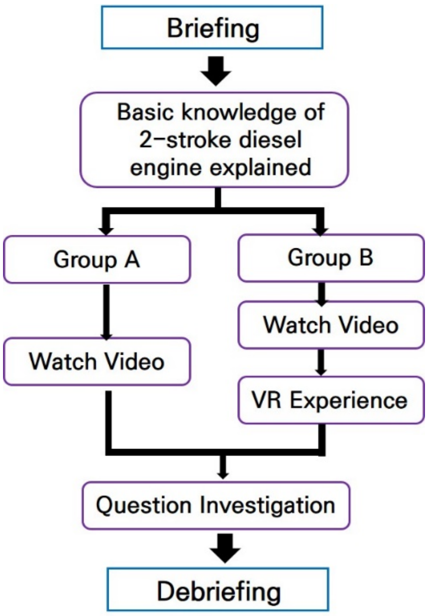

Figure 10: Curriculum Application Flowchart

The curriculum application flowchart of the two groups is illustrated in **Figure 10**.

4.2 Composition of understanding questionnaire

After the completion of education, a questionnaire survey was conducted to measure the education achievement of the two groups. The questionnaire consisted of general questions about the students, their understanding of the education, and their opinions about it.

The contents of the questionnaire are presented in **Table 8**.

Table 8: Contents of questionnaire

Content Elements	No	VR curriculum
General information	1	Have you ever heard of VR equipment?
	2	Have you ever experienced VR through games, training, etc.?
	3	Have you ever learned about a two-stroke diesel main engine?
Understanding of training	1	After training, did you have a sufficient understanding of the principles of the 2-stroke diesel engine?
	2	After training, did you have a sufficient understanding of the structure of a 2-stroke diesel engine?
	3	After training, did you have a sufficient understanding of the accessories of a 2-stroke diesel engine?
	4	After training, did you have a sufficient understanding of the combustion of a 2-stroke diesel engine?
Education opinion	1	Do you think that training with VR(Video) has helped you acquire relevant knowledge about 2-stroke diesel engine?
	2	If so, in what way do you think it helps?
	3	If not, what do you think is the problem?
	4	Describe the advantage and disadvantage of VR(Video) you think.

4.2 Composition of understanding survey questionnaire

Students of Groups A and B completed the questionnaire in a separate location.

Most of the students were well informed about the VR equipment and it was confirmed that they had experience through exhibitions, games, and so on. It was also confirmed that the two-stroke diesel engine has been studied during the department class.

Therefore, the analysis was conducted on the understanding level of education, excluding the general and post-education review analysis of the questionnaire results. The questionnaire on understanding education and training consisted of 10 items and 20 detailed items on a total of four topics. The results of the questionnaire analysis for participants in Groups A and B are summarized in **Tables 9** and **10**, respectively. The average understanding of the detailed items was calculated on a scale of 10 points and expressed as a percentage (%).

Table 9: Questionnaire result of Group A

Questionnaire		Items	Detail items	Ave. understanding
1	Principles of the 2-stroke diesel engine	1	2	45%
2	Structure of a 2-stroke diesel engine	1	3	51%
		1	1	55%
		1	2	50%
3	Accessories of a 2-stroke diesel engine	1	3	45%
		1	2	47%
		1	2	43%
		1	2	43%
		1	2	45%
4	Combustion of a 2-stroke diesel engine	1	1	38%
Total		10	20	45.2%

The average level of understanding of students in Group A, who learned the detailed items of the curriculum through video, was 45.2%. Students in Group B, who learned through both videos and VR, had an average understanding of 66.7%, 21.5% higher than Group A. Although overall understanding improved for most items, in particular, understanding the characteristics of devices operating inside the crank chamber improved by 25%. Although it is difficult in reality, it is understood that there have been significant improvements in the items that sufficiently reflected the advantages of using VR equipment. Group A learned in a familiar environment since a method of watching video is often used in conventional education. However, since Group B learned in an environment that involves actual moving and wearing VR devices in addition to watching video, their interest in novelty seems to have influenced satisfaction evaluation.

Table 10: Questionnaire result of Group B

Questionnaire		Items	Detail items	Ave. understanding
1	Principles of the 2-stroke diesel engine	1	2	68%
2	Structure of a 2-stroke diesel engine	1	3	70%
		1	1	73%
		1	2	72%
3	Accessories of a 2-stroke diesel engine	1	3	65%
		1	2	64%
		1	2	66%
		1	2	67%
		1	2	70%
4	Combustion of a 2-stroke diesel engine	1	1	52%
Total		10	20	66.7%

The following is a brief description of the post-education review questionnaire items.

Group A, which learned only by watching videos, had no special reviews since it is a lecture method that is used frequently, but there were opinions that it was not realistic, difficult to understand, and boring. Meanwhile, Group B said that using VR equipment in addition to watching video helped understand the content of the training much better, arousing interest in a form of playing games, and being able to repeat lessons. However, there were some students who experienced dizziness when they wore the gear for a long time.

5. Conclusion

In this study, a two-stroke diesel engine curriculum utilizing VR educational equipment was developed and presented. The following items were developed considering the VR equipment characteristics and educational target.

- Diesel engine principles
- Diesel engine structure
- Diesel engine accessories
- Diesel engine combustion

To analyze the effects of the developed curriculum, Korea Maritime University conducted education for students and analyzed their understanding. The students were divided into Group A and B for understanding analysis. Group A learned by only watching videos of the educational content, while Group B combined video and VR learning. Consequently, the understanding of Group B, who had video and VR learning in parallel, was 21.5% higher than that of Group A, which learned by only watching videos.

This confirms that the introduction of VR curriculum into existing educational methods can improve educational effect and understanding. While there are certain limitations such as the high cost of equipment, dizziness, and lack of content, this could likely be solved considering the pace of technology development.

In the future, based on the results of this study, we plan to collaborate with VR developers to design VR programs and curriculum for various devices in the engine room.

Author Contributions

Conceptualization, J. J. Hur; Methodology, J. J. Hur and B. S. Roh; Software, B. S. Roh; Formal Analysis, B. S. Roh; Investigation, B. S. Roh; Resources, J. J. Hur and B. S. Roh; Data Curation B. S. Roh; Writing-Original Draft Preparation, B. S. Roh; Writing-Review & Editing, J. J. Hur; Visualization, B. S. Roh; Supervision, J. J. Hur; Project Administration, J. J. Hur

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