

# Virtual reality learning environments for vocational education: a comparative study with conventional instructional media on two-stroke engine

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**Abstract.** Virtual reality technology has been adopted as a modern learning media in vocational education. Nowadays, the practical learning needs complete equipment and tools to achieve the goal study. However, the conventional media requirement is a challenge for academician for learning process, specifically in automotive and machine areas. Virtual reality provides a solution for this problem, but still needs proper analysis on the impact of usability between conventional and VR media to which each learning objective is achieved. The case study used in this research is a two-stroke engine, which is currently a rare item in the real world. We replicated this two-stroke engine in the developed VR system using Unity game engine and Oculus quest. A comparison on the usability effectiveness on conventional and virtual reality methods was conducted using cognitive walkthrough, which follows the four steps of learning objective training. The result shows that three out of four learning objectives are similar with conventional objective training. One of the process on preparation for disassembly machine has slight difference with conventional training; faulty engine due from environment elements (liquid, rusty iron) was not included.

## 1. Introduction

Virtual reality provides a technology, which increases the efficiency and quality of training in the Industry Revolution 4.0 and learning environments imitating a real-life process or situation [1]–[6]. The development of engineering and technology gives the new opportunities for improving the educational of methods process. Specifically, an engineering education is related with machine such as automotive, manufacturing, and industry. Therefore, there is a need for educational virtual technologies development, especially, in the technology classified as rare as the two-stroke engine.



This paper describes the study on a VR training of a two-stroke engine simulator as an alternative learning environment for vocational training. Findings from this study is hoped to shed some ideas for future research and design for suitable VR training system that can be used in the automotive area. The main findings of this study can be highlighted as follows; firstly, it is evident that a suitable VR system can be used as an alternative to learn the subject of two-stroke engine. Secondly, this paper outlines the technical information on the design of the 3D model as well as the user interaction to support a realistic two-stroke engine simulation. Third is the evaluation of virtual reality for learning two-stroke engine with instructional media using cognitive walkthrough. The gap between VR and instructional media forms the basis for further product development, which the usability method is suitable for filling the gap.

The rest of this paper is organized as follows: a review on related research and methods is presented in Section 2. A detailed description on the related design and modelling process for this study is shown in Section 3. Section 4 outlines the settings of the experiments, while Section 5 provides a cognitive walkthrough evaluation result between the VR learning system and traditional methods. Section 6 presents the threat and validity of this research. And finally, the main conclusions, limitations and future works is presented in the last section.

## 2. Background and related work

In the context of skill training, virtual reality offers many advantages used in education field [5], [7], [8]. The virtual environment may allow students to learn practically, which enhance the learning and processing skill [7], [9], [10]. Modern engineering education supposes that the learning process needs to combine harmoniously of fundamental theoretical training with the skills of practical work on solving the real problems of the industry [9], [11]. Especially in automotive, the learning process needs specific tools and vehicle to archives each learning goals. Virtual reality technology is one of a variety of learning domains to improve immersive learning environment in vocational study.

Providing effective training for future workers can present significant challenges, requires access to real equipment or physical mock-ups [4], [12], [13]. Therefore, the usability side is crucial in the learning process following a lesson plan of subject. The usability method used to evaluate between VR and instructional media is a cognitive walkthrough. The cognitive walkthrough is a usability walkthrough technique that focuses primarily on the ease of learning of a product [14]. Which, the group of evaluators in this research have been collaborate with automotive engineering of education students. The cognitive walkthrough can be used in the during of the development process, which a process namely requirements, conceptual design, detailed design, implementation [14]. However, in this research the focus is on the comparison in implementation process with follow up the skill and experience user.

**Table 1.** Document and Material Required for the Cognitive Walkthrough.

Description	Required
User profile	Automotive engineering of education students
Task list	Four step based lesson plan : 1. Checking tools and requirement 2. Preparation for disassembly of two stroke 3. Disassembly procedures of two stroke engines 4. Reassembly procedures of two stroke engine
Action sequence of task	Include following information : Task, Users, and Interface.
Problem reporting form	Tasks based on lesson plan
Representation of the UI	Prototypes and working feature

The document and material required for the cognitive walkthrough in this research is shown as Table 1 namely, user profile, task list, action sequence of task, problem reporting form, and representation user interface. Learning method between instructional media and virtual reality needs to be measured to see

the comparison of the efficacy of this media in learning process. Therefore, the analysis of gap between user reactions between the real world training and virtual work training will be needed to evaluate the VR system.

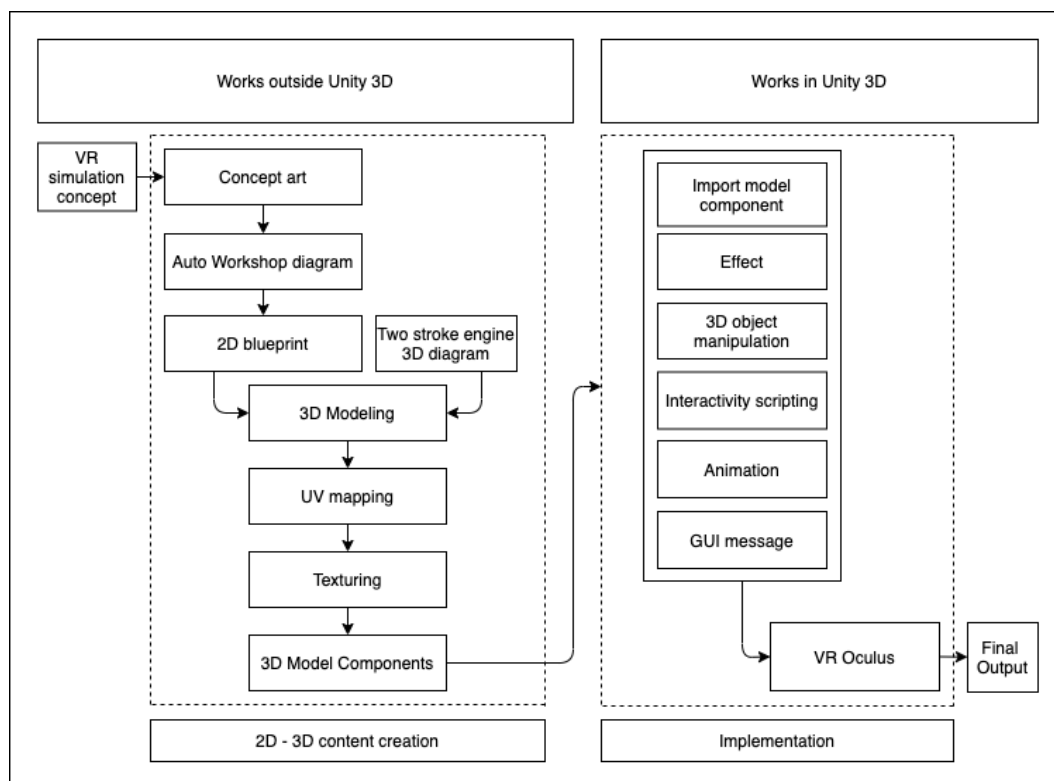
### 3. Modelling of VR two stroke engine

Modelling of the environment and engine components were done using SOLIDWORKS and Blender. Whereas, the components that control interactivity, object interaction, user behaviour, were implemented using Unity. The full development of the VR system involves the use of C# which is supported by Unity to implement the algorithms for navigation and behaviour [15]. The production phases of VR two-stroke engines were described on the modelling process.

#### 3.1. The modelling process

Modelling is an essential part of virtual reality system. The modelling phase was completed on the early phase of development. The virtual model of the two-stroke engine and workshop were created using SOLIDWORKS. The VR environment consists of these components; engine, room of workshop, and auto mechanic tools. The 3D workshop building is important to bring student engagement in the room of practical lesson. The two-stroke engine model was created following each component, which is shown on Figure 2.

Development phase was divided on two types of works. The first phase is the design work, which covers VR simulation concept and model content creation. The second is the work inside Unity environment on VR simulation development. The model content creation embraces 3D two stroke engine diagram and auto workshop diagram. Figure 1 gives detail of simulation production pipeline of development phase. The pipeline shows the task that needs to be completed before continuing the next step.



**Figure 1.** Simulator production pipeline for VR two stroke engine.

Figure 2 gives a diagram of the component of the two-stroke engine. The result of modelling shows as Figure 3 for engine, and Figure 4 for workshop.

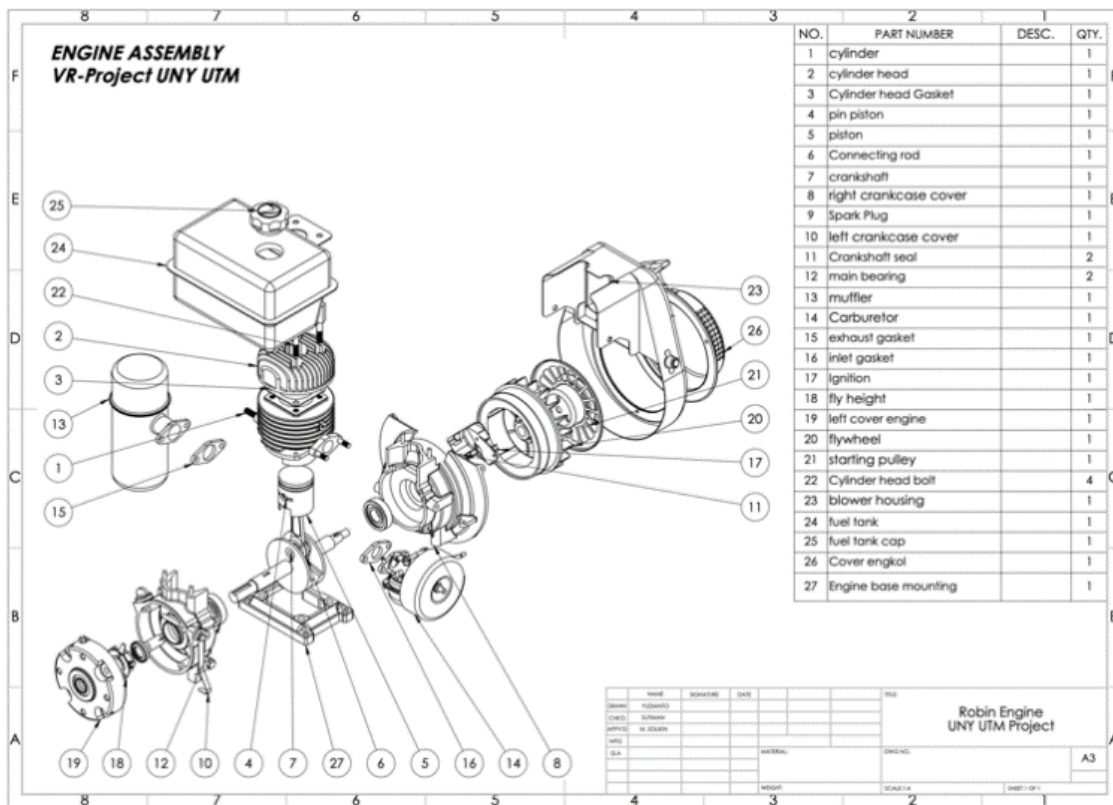


Figure 2. Modelling components.

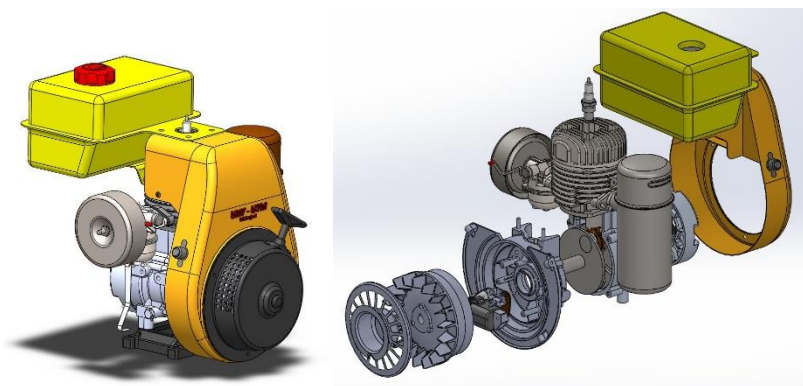
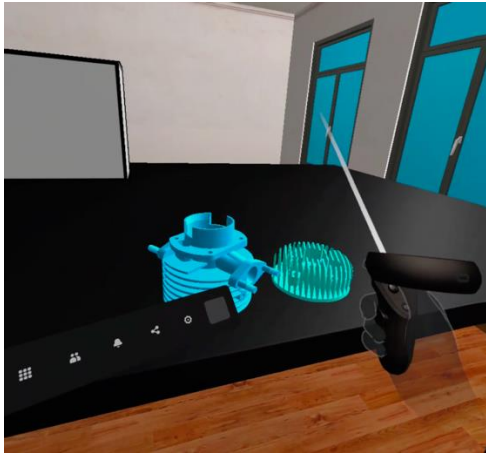


Figure 3. Engine Assembly.

## 4. Experiment

### 4.1. Implementation

The developed VR learning system was tested on a notebook with 16GB of RAM, NVIDIA GTX 1080 graphic card and 2.80GHz Intel i7-7700 3.60 GHz (8CPUs) processor. The user experienced the two-stroke engine simulation via the Oculus Quest. The development of the VR system used Unity version 2019.x3 and SOLIDWORKS version 2020. Figure 4 and 5 shows VR simulation with oculus in the process of implementation.



**Figure 4.** Simulation with controller.



**Figure 5.** Simulation with hand tracking.

#### 4.2. Participants

Next, we will explain the steps in verifying the validity of the VR platform for the two-stroke engines simulation. A total of 20 participants were involved in the experiment; of whom these volunteers have auto mechanic skill and had experienced the conventional training beforehand. Participants were recruited among the students of automotive engineering course at Universitas Negeri Yogyakarta from different semesters. The students were selected based on the subject program, who graduated of automotive engineering education targeted to be teachers and academicians specializing in automotive areas. The characteristic of study participants is presented in Table 2.

**Table 2.** Sample characteristic.

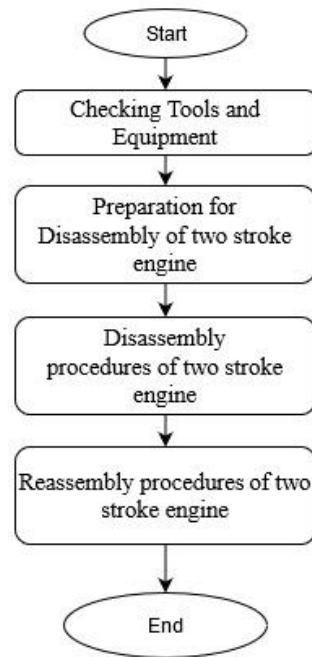
Data	Values
Number of subjects	20
Male subject	20
Female subject	0
Minimum age	19
Maximum age	24
Mean age	22
Virtual reality game expertise	2 Yes (10 %) / 18 No (90%)

Furthermore, all of subjects are male, with less/no virtual game expertise (90%). 2 of subjects declared some experience using VR with their smartphone. Since all participants has the skill needed in this experiment, it is convenient to compare conventional instructional media and virtual reality on training of two-stroke engine.

## 5. Cognitive walkthrough evaluation

### 5.1. Experiment description

The participants were tested with an instructional media and virtual reality. The test is composed of four steps, namely (1) checking tools and equipment, (2) preparation for disassembly of two stroke, (3) Disassembly procedures of two stroke engines, and (4) Reassembly procedures of two stroke engine. Immediately in after completing each step, participants were asked to complete tasks training. The flowchart of training procedure shows at Figure 6.



**Figure 6.** Flowchart of the training procedure.

### 5.2. Evaluation result

Usability evaluation is both an essential and challenging task in this research. Each of training parts have specific requirement based on the training module / curriculum. In this case, learning two-stroke engine involves four steps that were previously described on section 5.1. The first step is related to tools and equipment needed for student learning process. Table 3 gives a comparison result in the first step. Result shown between conventional method and virtual reality methods, each of tools and equipment fulfil 100%, which shows the similarity between both methods.

**Table 3.** Result comparison of Tools and equipment.

Tools and Equipment	Conventional Methods	Virtual Reality Methods
Wrench Set	YES	YES
Screwdriver Set	YES	YES
Torque Wrench	YES	YES
Special Tool; Flywheel Puller	YES	YES

Next step is a preparation for disassembly of two-strokes engine. Table 4 gives a detail comparison of conventional and virtual reality methods. The result shows a preparation for disassembly have a part that shows dissimilarity where the VR system cannot fulfill. The reason is for detailed material such as density of materials to classify a fragile object, any chemical elements that are not part of a main engine component, and other liquid machine that were not provided for the VR system. However, in this part, the step is more concise on VR system, in which a participant can complete faster and safer.

**Table 4.** Result comparison of Preparation for Disassembly.

Preparation for Disassembly	Conventional Methods	Virtual Reality Methods
1. When disassembling the engine, memorize where and how each part is assembled in order to be able to reassemble it correctly.	Yes	Yes
2. Take care not to damage packings and gaskets, which are fragile.	Yes	NO (Object not fragile)
3. In order to prevent missing and misplacing, group related parts together parts together, tentatively assembling them, immediately after disassembled each sub-assembly.	Yes	No (Handle by feature on VR)
4. Handle the disassembled part carefully, and wash them in kerosene.	Yes	No (Not required)
5. Use the correct tools in the correct way.	Yes	Yes
6. Standard tools required for disassembly and reassembly. <ul style="list-style-type: none"> <li>a. Work table</li> <li>b. Washing pan</li> <li>c. Disassembling tools</li> <li>d. Washing oil</li> <li>e. Emery paper, cloth</li> </ul>	Yes	Yes
7. Before starting to disassembly, the engine, drain fuel and lubricant.	Yes	No (Machine and Engine always ready)

**Table 5.** Result comparison of Disassembly Procedures.

Disassembly Procedures	Conventional Methods	Virtual Reality Methods
1. Fuel tank and fuel tank bracket <ul style="list-style-type: none"> <li>a. Disconnect fuel pipe between strainer and carburetor at carburetor side</li> <li>b. Remove mounting bolts and detach fuel tank from cylinder head or cylinder</li> </ul>	YES	YES
2. Air cleaner <ul style="list-style-type: none"> <li>a. Remove air cleaner cover and element</li> <li>b. Unscrew two bolts which clamped air cleaner base plate to carburetor and remove base plate</li> </ul>	YES	YES
3. Carburetor <ul style="list-style-type: none"> <li>a. Remove governor rod and rod spring from carburetor</li> <li>b. Remove carburetor from cylinder block</li> </ul>	YES	YES
4. Governor lever <ul style="list-style-type: none"> <li>a. Remove governor lever from governor shaft</li> <li>b. Remove governor spring from control lever</li> <li>c. Control lever and stop plate can be remove by losing wing-nut or bolt, but do not disassembly unless it necessary</li> </ul>	YES	YES
5. Muffler <ul style="list-style-type: none"> <li>A. Unscrew bolts or nut and remove it from cylinder</li> </ul>	YES	YES
6. Blower housing <ul style="list-style-type: none"> <li>a. Disconnect stop button wires from connector</li> </ul>	YES	YES

b. Unscrew bolts and remove blower housing from crankcase		
7. Recoil starter	YES	YES
a. Remove recoil starter from blower housing by unscrew the bolts		
b. Remove starting pulley from flywheel by losing bolts clamped		
8. Starting pulley and magneto	YES	YES
a. Remove starting pulley from flywheel		
b. Remove flywheel from crankshaft		
c. Remove spark plug cap from high tension cable of ignition coil and remove ignition coil from crankcase		
d. Take off the point cover and remove contact breaker and condenser, from crankcase		
9. Cylinder head	YES	YES
a. Remove spark plug from cylinder head		
b. Unscrew mounting special bolts and remove cylinder head from cylinder		
c. Remove cylinder head gasket from cylinder		
10. Cylinder	YES	YES
a. Remove cylinder from crankcase by removing nut and spring washer		
b. Remove cylinder gasket		
c. Remove intake pipe from cylinder		
11. Piston	YES	YES
a. Remove both sides piston pin clips		
b. Pull out piston pin and disconnect the needle bearing from small end of connecting rod		
c. Remove piston rings from piston by expanding the open ends of rings		
12. Governing plate	YES	YES
a. Pull out governor plate, governor sleeve, washer and clip from crankshaft		
b. Remove woodruff key		
13. Governing plate	YES	YES
A. Pull out governor plate, governor sleeve, washer and clip from crankshaft		
B. Remove woodruff key		

**Table 6.** Result comparison of Reassembly Procedures.

Reassembly Procedures	Conventional Methods	Virtual Reality Methods
1. Fuel tank and fuel tank bracket	YES	YES
a. Reassembly with reverse sequence based on disassembly procedures correctly		
2. Air cleaner	YES	No (Wash element part)
a. Wash elements before reassembly: outer and inner elements with gasoline, soak them into the mixed oil of 2-4 gasoline and 1 mobile oil		
b. Reassembly with reverse sequence based on disassembly procedures correctly		
3. Carburetor	YES	YES
A. Reassembly with reverse sequence based on disassembly procedures correctly		



4. Governor lever	YES	YES
a. Reassembly with reverse sequence based on disassembly procedures correctly		
b. Assembly shall be made securely including rotation adjustment		
5. Muffler	YES	YES
a. Reassembly with reverse sequence based on disassembly procedures correctly		
6. Blower housing	YES	YES
a. Reassembly with reverse sequence based on disassembly procedures correctly		
7. Recoil starter	YES	Yes
a. Reassembly with reverse sequence based on disassembly procedures correctly		
8. Starting pulley and magneto	YES	YES
a. Reassembly with reverse sequence based on disassembly procedures correctly		
b. Reassembly should include breaker point adjustment and timing adjustment		
9. Cylinder head	YES	No (Clean carbon from combustion chamber)
a. Clean carbon from combustion chamber and dirt from between the cooling fins of cylinder head. Check its mounting face for distortion		
b. Use new cylinder head gasket		
c. Cylinder head fin must be placed in parallel with crankshaft. Fasten with recommended fastening torque		
d. Apply the standard fastening torque for spark plug		
e. Reassembly with reverse sequence based on disassembly procedures correctly		
10. Cylinder	YES	YES
a. Clean carbon deposit from cylinder head and combustion chamber		
b. Replace cylinder gasket to the new one		
c. Intake cylinder should be positioned to the left against view from blower side. Apply oil to piston ring and cylinder walls, then after assembled the cylinder securely, make sure if the crankshaft rotates smoothly		
d. Apply the standard fastening torque of cylinder head and spark plug		
e. Reassembly with reverse sequence based on disassembly procedures correctly		
11. Piston	YES	YES
a. In reassembly of piston rings, if an expanding tool is not available, install rings by placing the open end of the ring on first land of piston, spread ring only far enough to slip over the piston and carry it into correct groove		
b. In reassembling the piston, position f mark of piston to blower side and reassemble the piston and connecting rod by firmly striking the piston pin and needle bearing		
c. Assemble piston pin clip		

- |   |     |     |
|---|-----|-----|
| d. Be sure that piston and connecting rod moves smoothly after reassembled    |     |     |
| e. Reassembly with reverse sequence based on disassembly procedures correctly |     |     |
| 12. Governing plate   | YES | YES |
| a. Reassembly with reverse sequence based on disassembly procedures correctly |     |     |
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The third and fourth steps are disassembly and reassembly of two stroke engine, which is almost similar between conventional and virtual reality methods. The differences are only in the use of the chemical and liquid engine in conventional workshop, but not on the VR system. Therefore, this part of the step was skipped on VR system. Overall, the VR system can fulfil the training on two-stroke engine instructions, based on actual steps on conventional methods. The result shows a VR system for training, specifically in automotive and machine area not only focus on engines components, but also needs detail of a component of virtual environment, such as liquid, dusk, that any material on used machine. Therefore, improve the similarity of between conventional and virtual reality methods for simulator training goal.

## 6. Threats to Validity

This paper has some limitations acknowledged, which may threaten its legitimacy. The potential threat of this paper is associated with less case studies. The case study use in this research is on a two-stroke engine machine, which is chosen because of the difficulty to find this type of engine in good condition nowadays. However, the specific major such as automotive engineering of education curriculum still needs to be delivered to students.

## 7. Summary

In this study, we developed a two-stroke engine simulator for student learning and training tools with new VR technology. Our proposed VR simulation developed for the current study provides an alternative for participants to learn the two-stroke engine with a four-step learning process. The evaluation results mainly show that the step on VR system has similarity with the conventional learning process. Moreover, the proposed VR systems has the potential of reducing total cost involved for the training institution compared to the conventional method, and improved safety side from any fragile part and hazardous chemicals. The only downside to current VR system is the limitation on the step of preparation for disassembly engine. Since the VR system has not included details on the objects (eg. density, chemical, rust), the risk due to errors in the object cannot be simulated successfully. The use of a VR two-stroke engine simulator however has many benefits over conventional learning methods. Most important advantage is it offers a learning environment with increased safety level and minimum risk to the participants.

The authors involved in this study are currently studying the efficacy of VR technology adoption into learning/training on various automotive machines such as motorcycle and car engine operations. It is also interesting to identify the factors that provide gaps for details of the virtual environment such as fluids, materials, electricity in machines that do not include diagrams but occur in real-world training. By identifying the factors that have been shown to influence each phase in the step-by-step training process, future researchers can begin to develop conceptual problem-solving models in the VR learning process.

### 7.1. Limitations and future works

We identified some limitations of the present work that require attention in future research. The present VR system is able to simulate the two-stroke engine scenario mainly by visual stimulation. However, are also factors characterized by fluid and chemical materials as well as by the heat and airflow that is

normally generated by the engine – these need some improvement to appear on the VR simulation. Future studies need to include natural stimulants such as olfactory and heat based on engine condition. It is hoped that this will increase the level of realism on user experience so that in turns will increase the effectiveness of the VR two-stroke engine simulation.

## References

- [1] I. Makarova, A. Boyko, K. Shubenkova, A. Pashkevich, and I. Giniyatullin, “Virtual laboratories: Engineers’ training for automotive industry,” *ICETA 2019 - 17th IEEE Int. Conf. Emerg. eLearning Technol. Appl. Proc.*, pp. 505–511, 2019, doi: 10.1109/ICETA48886.2019.9040074.
- [2] D. Rath, I. Satpathy, and B. C. M. Patnaik, “Augmented reality (Ar) & virtual reality (Vr)-a channel for digital transformation in industrialization fostering innovation & entrepreneurship,” *Int. J. Innov. Technol. Explor. Eng.*, vol. 8, no. 10, pp. 3228–3236, 2019, doi: 10.35940/ijitee.J1167.0881019.
- [3] M. Carfagni *et al.*, “Fast and Low Cost Acquisition and Reconstruction System for Human Hand-wrist-arm Anatomy,” *Procedia Manuf.*, vol. 11, no. April 2020, pp. 1600–1608, 2017, doi: 10.1016/j.promfg.2017.07.306.
- [4] X. Wu and G. Fei, “Research of virtual reality technology in automotive engine assembly teaching,” *Proc. - 2011 6th IEEE Jt. Int. Inf. Technol. Artif. Intell. Conf. ITAIC 2011*, vol. 1, pp. 167–169, 2011, doi: 10.1109/ITAIC.2011.6030177.
- [5] J. A. di Lanzo, A. Valentine, F. Sohel, A. Y. T. Yapp, K. C. Muparadzi, and M. Abdelmalek, “A review of the uses of virtual reality in engineering education,” *Comput. Appl. Eng. Educ.*, vol. 28, no. 3, pp. 748–763, 2020, doi: 10.1002/cae.22243.
- [6] W. X. Quevedo *et al.*, “Virtual reality system for training in automotive mechanics,” *Lect. Notes Comput. Sci. (including Subser. Lect. Notes Artif. Intell. Lect. Notes Bioinformatics)*, vol. 10324 LNCS, pp. 185–198, 2017, doi: 10.1007/978-3-319-60922-5\_14.
- [7] M. Akçayır and G. Akçayır, “Advantages and challenges associated with augmented reality for education: A systematic review of the literature,” *Educ. Res. Rev.*, vol. 20, pp. 1–11, 2017, doi: 10.1016/j.edurev.2016.11.002.
- [8] O. T. Laseinde, S. B. Adejuyigbe, K. Mpofo, and H. M. Campbell, “Educating tomorrows engineers: Reinforcing engineering concepts through Virtual Reality (VR) teaching aid,” *IEEE Int. Conf. Ind. Eng. Eng. Manag.*, vol. 2016-Janua, no. December, pp. 1485–1489, 2016, doi: 10.1109/IEEM.2015.7385894.
- [9] I. Makarova, R. Khabibullin, E. Belyaev, and A. Bogateeva, “The application of virtual reality technologies in engineering education for the automotive industry,” in *2015 International Conference on Interactive Collaborative Learning (ICL)*, 2015, pp. 536–544, doi: 10.1109/ICL.2015.7318086.
- [10] M. Belani, “Evaluating Virtual Reality as a Medium for Vocational Skill Training,” pp. 1–8, 2020, doi: 10.1145/3334480.3375027.
- [11] K. Tcha-Tokey, E. Loup-Escande, O. Christmann, and S. Richir, “A questionnaire to measure the user eXperience in immersive virtual environments,” *ACM Int. Conf. Proceeding Ser.*, 2016, doi: 10.1145/2927929.2927955.
- [12] D. W. Carruth, “Virtual reality for education and workforce training,” *ICETA 2017 - 15th IEEE Int. Conf. Emerg. eLearning Technol. Appl. Proc.*, 2017, doi: 10.1109/ICETA.2017.8102472.
- [13] C. Sagnier, E. Loup-Escande, D. Lourdeaux, I. Thouvenin, and G. Valléry, “User Acceptance of Virtual Reality: An Extended Technology Acceptance Model,” *Int. J. Hum. Comput. Interact.*, vol. 36, no. 11, pp. 993–1007, 2020, doi: 10.1080/10447318.2019.1708612.
- [14] C. Wilson, “Chapter 4 - Cognitive Walkthrough,” in *User Interface Inspection Methods*, C. Wilson, Ed. Boston: Morgan Kaufmann, 2014, pp. 65–79.
- [15] “Unity Documentation,” 2020. .