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The Impact of Automotive Maintenance Education via VR Equipment on Students' Learning Outcomes: A Focus on Formative Assessment in Education

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ABSTRACT
This study analyzed in-depth the impact of virtual reality (vr) and augmented reality (ar) technologies on learning outcomes in automobile maintenance education, and attempted to evaluate the effect of learning experiences centered on the process evaluation type qualification system from various angles through comparison between traditional and vr-based education methods. This comparative analysis is expected to contribute to clarifying the effectiveness and limitations of vr education, and it will play an important role in deriving practical and specific suggestions for the improvement of the education and training system and the development of the national technology qualification system by providing empirical data on learners' skill acquisition.

The main purpose of this study was to explore the background and application form of vr and ar in vocational education, and to analyze major issues arising in this process. To this end, we tried to use vr/ar in vocational education learning situations for learners with no automobile maintenance experience. As a result of the study, it was confirmed that vr and ar technologies in the vocational education field are being used as effective means to induce active participation of learners, provide repetitive practice opportunities, and replace high-risk and high-cost practice.

This study presents an innovative approach to enhancing the effectiveness of automobile maintenance education and training in a rapidly changing industrial technology environment, and is expected to make a practical contribution to the improvement and development of the national technology qualification system. In addition, this study will contribute to presenting a new paradigm for industrial education by exploring in-depth the possibility of utilizing vr and ar technologies in the design and operation of future education and training systems.

In addition, it was pointed out that the educational performance was low due to the lack of practice and review time for trainees compared to the training time as a problem with the traditional automobile maintenance education method. Therefore, this study studied the effect of vr education after school on trainees receiving automobile maintenance process evaluation type education, and tried to contribute to improving educational outcomes by revitalizing vr education. The issues derived from this study are expected to be used as step-by-step guidelines for vocational education field officials considering introducing vr education data for automobile maintenance in the future.

Keywords: Automotive Maintenance, Vocational Training, Course Evaluation, Virtual Reality (Vr), Augmented Reality (Ar)

1. INTRODUCTION

The rapidly changing industrial technology environment of the modern era requires fundamental changes in the education and training system. In particular, in the field of automobile maintenance that requires a high degree of expertise and precision, this change appears as an essential task, not an option [6],[18]. The traditional education method has been used to strengthen job competency for a long time, but does not sufficiently reflect the rapidly changing technical requirements and complex industrial environment. Traditional automobile

maintenance education has mainly attempted to improve job competency through theoretical lectures and practice-oriented approaches, but this method reveals limitations in responding quickly to the latest technological development and changes in field demands.

In order to overcome these limitations, recently, education and training systems using virtual reality (VR) and augmented reality (AR) technologies have been rapidly introduced into the industrial education field. VR and AR technologies provide a concentrated learning environment and present the possibility that learners can effectively combine theory and practice [20]. VR technology allows learners to experience maintenance work similar to the real thing in a virtual environment, so that learners can reinforce their job performance skills through practice. On the other hand, AR technology provides digital information on the other hand, by overlapping it with the real environment, providing necessary information in real time in the practice process and helping to improve job performance. This technical approach plays an important role in maximizing the learning effectiveness of trainees and promoting practical skill acquisition. Therefore, it was said that it was necessary to pay active interest in the introduction of usable AR [8].

The main purpose of this study is to analyze in-depth the effect of the process evaluation type qualification of the national technology qualification system on automobile maintenance education [11]. The national technology qualification system is an important system that publicly certifies the competencies required in the industrial field, and aims to verify the expertise of qualifiers and meet the needs of the industry. However, the existing test-type qualifications have been criticized for not sufficiently reflecting the actual job performance ability of the qualification acquirer.

SMEs and vocational training institutions need to continuously develop systematic and scientific customized operation plans to improve the efficiency of the learning operation system [16]. Companies demand indicators that can objectively evaluate job performance, but the existing qualified qualification system does not meet these requirements and is not recognized as a discriminatory means in the hiring process by companies that are consumers of qualifications [5],[15]. In addition, the competency-oriented national qualification system is also not meeting the expectations of companies. To solve this problem, the government is promoting the introduction of a Korean-style education system with the aim of realizing a competency-oriented society [15],[18].

In particular, the government is promoting innovation in the qualification test and evaluation method by introducing a course evaluation-type qualification system based on the National Competency Standards (hereinafter referred to as NCS). The course evaluation-type qualification system adopts a method of systematically designing and evaluating the curriculum so that learners can cultivate practical job competencies, which shows a fundamental difference in the criteria and evaluation method from the existing test-type qualification system [15]. These differences directly affect the validity and objectivity of the qualification system and emerge as an important factor in securing consistency and reliability of the qualification test process [11]. Accordingly, this study aims to examine in-depth the validity of the problem derived through discussion on the educational use of VR [8],[9].

Therefore, from this background, this study seeks to explore the innovative development of the automobile maintenance education and training system and systematically evaluate the practical effects of the course evaluation type qualification system. In particular, this study focuses on providing the theoretical and empirical basis necessary for the development of learner-centered customized educational tools by comprehensively analyzing the effect of the course evaluation type qualification system on trainees' learning outcomes and job performance ability. Through this, it is intended to verify the efficiency of the education system according to the learner's skill level and to prove whether VR technology can substantially contribute to the improvement of the quality of education.

Furthermore, this study focuses on examining the process of introducing and utilizing VR and AR technologies in vocational education and identifying major issues that may arise in this process [6]. To this end, by comparing and analyzing the field training process between learners who have received VR education and those who have received traditional education, major issues to be considered when introducing and utilizing VR and AR technologies in the future vocational education field were systematically analyzed [6]. Based on this analysis, the main conclusions and discussions for the introduction and use of VR and AR technologies in the field of vocational education are to be drawn.

This study will examine in-depth the impact of VR technology on trainees' learning outcomes in automobile maintenance education, and evaluate the effect of learning experiences centered on the process evaluation type qualification system from various angles through comparison between traditional and virtual reality-based education methods. This comparative analysis will contribute to clarifying the effectiveness and limitations of VR education more clearly by providing empirical data on learners' skill acquisition. These findings are expected to play an important role in suggesting the direction of improvement of the education and training system and drawing practical and specific suggestions for the national technical qualification system and the

criteria for process-type performance evaluation.

In this way, this study presents a new approach to enhancing the effectiveness of automobile maintenance education and training in a rapidly changing industrial technology environment, and will be able to make a practical contribution to the improvement and development of the national technical qualification system. Furthermore, this study will contribute to presenting a new paradigm for industrial education by exploring in-depth the possibility of using VR and AR technologies in the design and operation of future education and training systems.

2. THEORETICAL BACKGROUND

Virtual Reality (VR) technology is a cutting-edge technology designed to make users feel a computer-generated virtual environment feel real, and its main goal is to provide a high sense of immersion and reality by elaborately reproducing situations or environments that are difficult to experience physically. These technologies are collectively referred to as various types of immersive media, and their characteristics are discussed by being divided into virtual reality, multi-user virtual environment, and mixed reality [9]. VR technology consists of hardware and software that integrates various sensory information and supports users to interact with virtual environments.

Hardware components include head-mounted displays (HMDs) that provide visual information, stereo speakers that provide stereoscopic sound, and haptic devices that provide tactile feedback, and the senses of stimulation and response of five senses (visual, auditory, tactile, olfactory, and taste) from the outside are transmitted from the surrounding environment to the educator [4],[13]. In terms of software, content and applications act as important factors that determine the quality of the user experience, and various technologies are used to optimize user interfaces (UI) and user experience (UX). These technologies can be defined as the totality of technologies that intentionally deceive the user's sensory organs to recognize and experience the virtual world as if it were real, and in particular, in the Virtual Training System (VTS) for education and training, these hardware and software elements are organically combined to provide learners with highly intensive and effective learning experiences. In this respect, VR technology is positioned as an important tool that can contribute to improving the quality of education and training.

In recent years, VR technology has been attracting attention as an alternative that can overcome the limitations of traditional teaching methods. In particular, VR-based virtual training systems are actively being introduced in highly specialized technology education such as automobile maintenance. It can be said that the process of learning and educating learners on knowledge, skills, and attitudes learned through learning in the environment of automobile maintenance education is carried out through continuous and effective education [7]. This allows learners to safely and cost-effectively experience various work situations they may face in real life, and contributes to overcoming educational constraints arising from limitations of physical resources. Education using VR technology provides learners with a high degree of immersion and is effective in enhancing their skill proficiency through repetitive practice in a simulated environment. Several studies have reported that VR-based training outperforms traditional education methods in terms of learners' memory, performance ability, and learning continuity [2]. However, in-depth research is still needed considering various characteristics such as learner's career, skill level, and learning style, along with systematic evaluation of the educational effect of VR training.

The theoretical framework of virtual reality-based education and training In order to understand the effects of virtual reality-based education and training, it is necessary to discuss the advantages of VR from the perspective of learning theory and cognitive psychology. The Immersion Theory argues that the more deeply a user is immersed in a virtual environment, the greater the learning effect [12]. This suggests that the high level of immersion provided by the VR system strengthens the learner's attention and enables him or her to perform learning tasks more effectively. It explains that optimal learning outcomes can be obtained when an individual is fully immersed in a task, and VR theoretically provides an environment in which learners can experience a flow state. In addition, the process of actively constructing knowledge by learners is emphasized, and VR is very suitable for providing such a constructive learning environment [3]. Learners construct knowledge through their own experiences by exploring and manipulating them directly in a virtual environment, which positively affects the continuity of learning and maintaining memory.

The introduction of virtual training systems in automobile maintenance education goes beyond simply complementing theoretical education and has become a key educational tool that actually replaces or reinforces the practice environment. Compared to traditional educational methods, VR-based virtual training improves skill proficiency by providing learners with repetitive practice opportunities, which in turn contributes to reducing learners' errors and maximizing their learning effects [12]. These virtual training systems have the advantage of providing high-risk and high-cost practice opportunities in particular, and provide learners with the opportunity to experience various scenarios without physical and financial constraints [12]. In addition, VR-

based education supports learners to internalize knowledge and acquire practical skills through direct experience and reflection [1]. However, the effectiveness of virtual training may differ depending on the learner's career level, skill proficiency, learning style, etc. For example, VR training that provides visual cues or step-by-step guidance may be useful for novice learners, but such support may be unnecessary or rather disturbing for already skilled professionals. Therefore, the virtual training system should provide customized learning experiences tailored to the learner's personal characteristics, and accordingly, it is necessary to develop tools to measure learning outcomes [7]. This emphasizes the importance of an educational approach that reflects learners' individual differences, and suggests that it is essential to reflect these personal characteristics in education using VR technology.

Comparison between Virtual Reality and Augmented Reality and Application in Vocational Education The introduction of VR and AR in vocational education is focused on strengthening the active participation of learners and expanding practical opportunities [19]. Augmented reality is a technology that superimposes virtual objects on the real world viewed by users [18] that allows VR to safely simulate high-risk situations by completely immersing learners within a virtual environment [9], whereas AR combines the real world and digital information so that learners can immediately obtain the information they need in a real work environment. We explain that the combination of VR and AR can provide new learning experiences that cross the boundaries of virtual and reality, which will provide learners with richer and more practical educational experiences. AR can be particularly useful in collaborative learning or game-based learning, and the development of various teaching and learning strategies using it is required.

Directions for VR and AR Technology Development in Future Vocational Education Virtual reality and augmented reality technologies are expected to play an important role in future vocational education [19]. In particular, for the effective improvement of the virtual training system, it is essential to develop customized learning contents suitable for the learner's career and skill level [10]. In order to implement such customized learning, the importance of adaptive learning systems is emphasized, and VR and AR technologies can promote the introduction of such systems. It is also important to establish an environment in which multiple learners can access at the same time to conduct cooperative learning. In the future, the development of mixed reality (MR) technology that integrates AR and VR is expected to provide a learning environment that crosses the boundaries of reality and virtuality, which will provide learners with richer and more practical educational experiences.

This study emphasizes the need for a systematic and scientific approach that reflects the diverse characteristics and needs of learners to maximize the educational effect of the virtual training system [14]. Through this, it is expected to improve the quality of education and training in specialized technical fields such as automobile maintenance, and further contribute to the development of the national technical qualification system/

3. TEACHING METHODS

This study applied a course evaluation-type education method based on the National Competency Standards (NCS) to systematically improve learners' technical competencies and use tools to evaluate them effectively [11].

The level of maintenance of manpower produced by automobile-related educational institutions tends to not meet the level required by the field [14]. Therefore, NCS is a national standard that standardizes job performance capabilities required in industrial sites, and in this study, a curriculum focused on specific competency units such as inspection and maintenance of engine body maintenance was designed in accordance with this standard. Each competency unit consisted of about 30 to 50 hours of technical training, and it aimed to strengthen the learners' comprehensive competencies by integrating theoretical understanding and practical experience.

3.1 Traditional teaching methods

As the first step of education, education based on traditional teaching methods was conducted. This course focused on learning theoretical knowledge about the inspection and maintenance of the engine main body and making it applicable through the actual practice process. In the traditional education method, textbooks and practical equipment were used to allow learners to systematically learn the maintenance procedure. The theoretical lecture dealt with the structural elements and operating principles of the engine, and the theoretical background related to the maintenance procedure, and in the practice process, the connection between theory and practice was strengthened by performing step-by-step procedures of actual maintenance work. However, the existing traditional education method focused on instructors delivering and mastering concepts and values to learners, but there was a limitation as it required a single and uniform thinking [20].

The existing traditional automobile maintenance education method was carried out as shown in [Fig 1]. By disassembling and assembling the part shown in the appearance of the real object to be maintained, the check for internal abnormalities consists of a structure that can only be confirmed by breaking away from the appearance of the engine [Fig 2].

Figure 1. Engine maintenance

Figure 2. Engine body inspection

The main components of the engine, the mechanical operation mechanism, and the main theories related to engine maintenance were dealt with in-depth in the theory education for automobile maintenance, and this theoretical basis became an essential basis for performing actual maintenance work in the practice process. Practical training allowed learners to increase their technical skills through accurate performance of each maintenance stage, and after the curriculum was completed, a checklist was used to quantitatively measure learners' performance. The first evaluation was conducted on 22 learners (19 males and 3 females) who had no experience in automobile maintenance, and the checklist consisted of items to evaluate the accuracy, efficiency, and problem-solving ability of each maintenance work.

3.2 Virtual Reality (VR)-based education

An educational method that combines traditional education and VR technology was provided. The VR education method allows learners to focus more by allowing them to experience and learn complex maintenance tasks that are difficult to experience directly in real life in a virtual environment. VR education is recently attracting attention as an innovative method that reinforces learners' practical competencies and maximizes educational effectiveness in the field of educational engineering and industrial education. In previous studies, it was said that infusion education has a lot of difficulties in adapting to the practical field [20], and it is effective to use other educational media for quick and efficient educational results. In this study, the curriculum was changed so that learners could experience maintenance work similar to the real world in a virtual environment through VR education.

[Fig 3] shows the work site in a space that forms the same structure as the automobile maintenance site in a virtual reality space. An education system was established to inspect and maintain the engine while maintaining the sense of the site as shown in [Fig 4]. In addition, since the configuration of the engine using software is opaque, a system that can more precisely manage engine maintenance through simulation of a transparent engine is established beyond the limit of being able to check the inside only when disassembled.

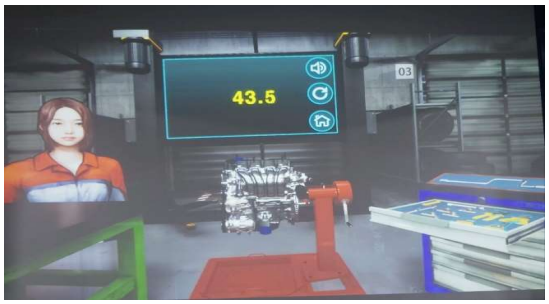

Figure 3. VR Screen Settings

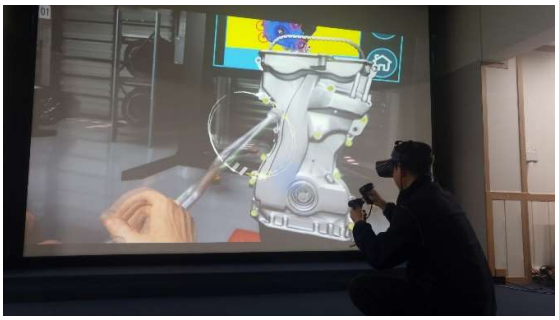

Figure 4. Engine Inspection with VR

The automobile maintenance training system requires image recognition and processing technology suitable for the characteristics of the maintenance training [18]. VR content should be designed based on the same maintenance work covered in traditional education, and it is configured to practice the inspection and maintenance procedures of engine maintenance step by step in a virtual environment. Since the driving operation is different from the real thing in the actual simulation [13], in the VR environment, learners were allowed to virtually experience various work situations that can be encountered in the actual maintenance site through various simulated scenarios. As a result of applying it to automobile maintenance education, it was found that the actual performance capabilities of learners who applied VR were further improved [8]. The

virtual environment of VR can provide various scenarios without the constraints of physical resources, and it is designed so that learners can improve problem-solving and situational response capabilities. One of the characteristics of VR education is that maintenance work can be performed through a 3D virtual environment in which learners can directly interact [17]. This allows learners to realize the complexity and diversity of maintenance work without directly receiving feedback from the actual work environment. In addition, VR education provides an opportunity for learners to repeatedly practice, and supports them to improve their understanding through real-time feedback on each task stage.

As the first step of education, education based on traditional teaching methods was conducted. This course focused on learning theoretical knowledge about the inspection and maintenance of the engine main body and making it applicable through the actual practice process.

3.3 Evaluation Results of VR Education Method Changes

After completing traditional VR education, a second evaluation was conducted using the same checklist. The second evaluation was conducted to measure how effectively the skills and knowledge acquired through VR education were applied in the practice process. The evaluation method was conducted through internal simulation evaluation of the national qualification test to compare the performance of the traditional education method and the VR education method. The application of these educational methods clearly reveals the difference in performance between traditional and VR-based education methods, and has become a very important basic data for evaluating how effective VR education is in improving learners' actual job performance skills.

Table 1 is an evaluation data that appears as a learning activity that has undergone internal evaluation.

[Table 1] Results of learning activities

Traditional education (1st internal evaluation)						
Course of study	Training Course for Qualification Acquisition of Automobile Maintenance Industry Engineer					
A subdivision	Automobile chassis maintenance			15060303		
Coursework	Engine maintenance			1506030201_18v4		
Evaluation date	April 14-15		valuation		1	
No.	Name	Test-1	No.	Name	Test-1	Note
1	Student 1	60	13	Student 13	59	
2	Student 2	63	14	Student 14	65	
3	Student 3	65	15	Student 15	69	
4	Student 4	69	16	Student 16	65	
5	Student 5	72	17	Student 17	67	
6	Student 6	63	18	Student 18	65	
7	Student 7	59	19	Student 19	72	
8	Student 8	67	20	Student 20	69	
9	Student 9	63	21	Student 21	67	
10	Student 10	67	22	Student 22	67	
11	Student 11	63	23			
12	Student 12	71	24			
Average			65.77			

Virtual reality education (2nd internal evaluation)						
Course of study	Training Course for Qualification Acquisition of Automobile Maintenance Industry Engineer					
A subdivision	Automobile chassis maintenance			15060303		
Coursework	Engine maintenance			1506030201_18v4		
Evaluation date	May 2-3		valuation		1	
No.	Name	Test-1	No.	Name	Test-1	Note
1	Student 1	83	13	Student 13	89	
2	Student 2	83	14	Student 14	80	
3	Student 3	85	15	Student 15	85	
4	Student 4	72	16	Student 16	85	
5	Student 5	72	17	Student 17	89	
6	Student 6	63	18	Student 18	71	
7	Student 7	85	19	Student 19	72	
8	Student 8	89	20	Student 20	89	
9	Student 9	71	21	Student 21	89	
10	Student 10	85	22	Student 22	89	
11	Student 11	89	23			
12	Student 12	72	24			
Average			81.23			

When the learner's evaluation score for the internally evaluated data was shown, it was confirmed that about 15 to 20% of the filial piety was generated in the difference between the evaluation method of the existing traditional curriculum and the education method through VR. This can be seen as proving the effective aspect of education in the theoretical background of previous studies.

Considering that the acceptance criteria for the performance evaluation passing test shown in [Fig 5] are 60 points, it can be seen that the increase in the acceptance rate by VR education has a significant impact, and depending on the trainees, differences in educational acquisition due to VR or AR adaptation may occur. However, according to the evaluation of trainees shown in this study, the acceptance rate of VR education has risen to a fairly high level.

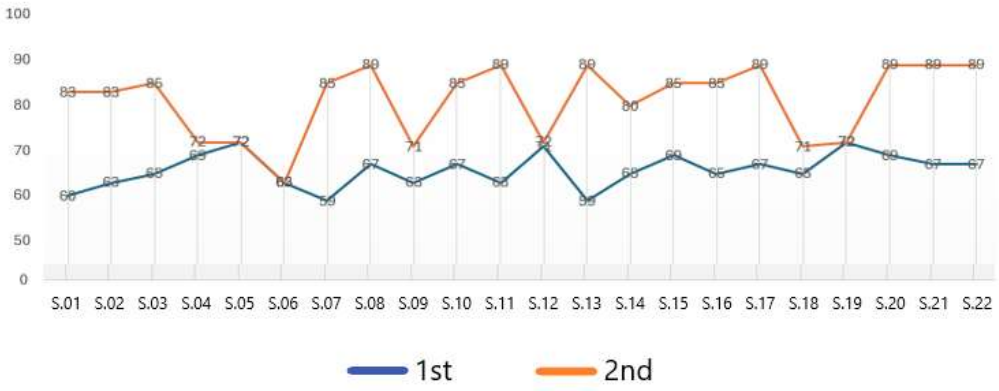

Figure 5. Evaluation Graph

The T-test was conducted through internal evaluation data. The t-statistic (t-statistic): -2.34 shown in [Fig 6] means that the average difference between the two groups is 2.34 times the standard error, and a negative number shows that the average of the traditional education method is lower than the average of the education method using VR programs. p-value: 0.021 represents the probability that this difference will occur accidentally, and in general, if the p-value is less than 0.05, the difference between the two groups is judged to be statistically significant. Therefore, when the t-statistic is -2.34 and the p-value is 0.021, the difference in evaluation scores between the traditional education method and the education method using VR programs is statistically significant.

Independent Variable	Mean Score	t-Statistic	p-Value
Traditional Education Method	65.18	-2.34	0.021
VR Program Education Method	81.91	-2.34	0.021

[Fig 6] T-test

4. CONCLUSION

This study analyzed the application effect of VR technology and course evaluation type education method based on the National Competency Standards (NCS) in the field of automobile maintenance education. NCS is defined as a systematic and standardized standard for job performance required in industrial sites, and in this study, a curriculum was designed centering on specific competency units such as inspection and repair of engine body maintenance. Through this, it aims to improve learners' technical competence. The main purpose of this study is to clarify the educational effect of each method by comparing traditional and VR-based education methods.

In the traditional educational method, theoretical lectures and practice were combined to allow learners to systematically acquire basic theories and practice procedures for engine maintenance. The theoretical lecture explained the structure and operating principle of the engine, and in the practice process, the link between theory and practice was strengthened by directly performing the step-by-step procedure of maintenance work. This method contributed to enhancing basic skill acquisition and practical application ability, but there were certain limitations in the learner's skill acquisition due to the limitations of physical resources and limited practice opportunities. It is required to ease the organization standard so that flexible curriculum operation is possible by applying various teaching methods whose educational effect has been verified [5].

On the other hand, VR-based education provides an opportunity to experience complex maintenance tasks in a virtual environment and enhances learners' immersion by virtually implementing various scenarios that are difficult to experience in reality. It has been confirmed in various studies that the use of AR and VR for education is effective in academic achievement, learning immersion, and interest [4]. VR education effectively narrowed the gap between theory and practice by allowing learners to repeatedly perform real-life maintenance tasks [17]. VR content was designed based on the maintenance work dealt with in traditional education, which helped learners improve problem-solving and situational response skills in a virtual environment. The

concentrated learning environment and real-time feedback of VR education played an important role in enhancing learners' technical skills and provided the advantage of experiencing various scenarios virtually.

In this study, data were collected to prove that VR education can improve learners' ability to acquire skills and apply them in practice more effectively than traditional education methods. As a result of the analysis of the curriculum, learners who received VR education showed a higher level of technical performance in the practical process, suggesting that the intensive and repetitive learning environment of VR education promotes practical skill acquisition for learners. Systematic stability should be prioritized by investing in the establishment of learning facilities or operating systems that are physical resources rather than financial investment in human resources [16]. These findings strongly support that VR education method can be effectively applied to the use of qualification test education for specialized technology education such as automobile maintenance. The introduction of VR technology is expected to establish itself as an innovative education method that can safely and cost-effectively provide high-risk and expensive practice opportunities through repeated practice [8]. Future research needs to expand the effect of VR education to other job fields and analyze the impact of VR education on education and training in various industries in-depth. In addition, it is important to continuously improve VR educational content and develop customized education tailored to the individual characteristics of learners, and a mixed approach between VR and traditional education methods can also be considered. This approach will be able to meet the diverse needs of learners and provide a more effective educational environment.

This study confirmed that NCS-based course evaluation type education and VR education methods are effective in systematically improving learners' job performance, which provides important implications for the design and operation of vocational education and training programs in the future. The use of VR technology is an educational method that reflects the actual competencies required in the industrial field and will be evaluated as an important factor leading the innovative development of education and training.

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