

Improving the Critical Thinking Ability of Students of Vocational Schools Using Portable Multi CDI Ignition Systems based Virtual Reality

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Abstract. Improving critical thinking skills is imperative in 21st-century education, especially at the Vocational High School (SMK) level. This article highlights the limited mastery of critical thinking among vocational school students, especially in engineering and the motorbike business. The proposed approach to improve these skills involves using a multi-CDI portable motorcycle ignition system trainer in problem-based learning. Through the Problem-Based Learning approach, students are invited to identify damage, explain the cause, apply repair procedures, analyse repair results, and evaluate the results. Appropriate media and learning methods are recognised as the key to creating unique interaction patterns, bringing a cognitive dimension to the learning process. The main focus is the student-centred approach because it is a key factor in improving students' critical thinking skills in vocational schools. Thus, this article proposes concrete and relevant solutions to advance the critical thinking skills of vocational school students, especially in engineering and the motorbike business.

Keywords: critical thinking; ignition trainer; learning; multi-CDI; thinking skills; vocational schools.

INTRODUCTION

Critical thinking is a key ability that students must master in the 21st century. This ability will form high-level attitudes, discipline and skills in effectively identifying, analysing and solving problems [1]. Mastery of this ability will provide confidence in making decisions about every problem faced [2]. In addition, critical thinking is the process of consciously processing information to ensure accuracy in determining actions and decisions [3]. This will have implications for increasing the ability to associate problems with past experiences that are appropriate to the problems faced [4] so that the resulting solutions to problems are effective in overcoming the problems faced [5].

Vocational High Schools, as formal secondary-level educational institutions, focus on developing students' skills in certain fields [6] by equipping students with the knowledge and technical abilities needed in the world of work [7]. Therefore, the education system and learning tools for Vocational High Schools must be in the same conditions and situations as the work environ-

ment [8]. So that Vocational High School graduates can master general, work, and problem-solving skills [9]. The challenges of global life require Vocational High Schools to provide 21st-century skills for their students to think critically and solve problems [6].

Through critical thinking skills, it is hoped that vocational school students will be competent in analysing problems, finding creative solutions and ideas and applying them practically in life [10]. These competencies will help them face competition in the work and entrepreneurship world. Critical thinking skills make the assessment process more careful, give the ability to solve complex problems and make communication skills in the workplace more effective [11]. Workers with critical thinking skills will greatly contribute to their workplace, especially the ability to adapt to certain situations, provide innovative suggestions and ideas, and be careful in decision-making, especially at certain levels [12]. Meanwhile, critical thinking skills help entrepreneurs develop self-regulation skills at a high level [13].

The vehicle maintenance and repair field is not limited to dismantling and installing vehicle components. Identifying, analysing and resolving problems (damage) that occur in vehicles requires thinking critically [14]. Therefore, the learning carried out must develop critical thinking skills to solve problems in the workplace [15]. In learning, efforts to develop critical thinking skills are carried out through interactive, dynamic learning and encouraging active participation of students [16], packaged in the form of experiment-based learning [17]. In developing the high school curriculum, project-based learning modules [18] are incorporated, emphasising hands-on, experiential learning where students actively engage in real-world projects to deepen their understanding of concepts and develop essential skills such as critical thinking, problem-solving, and collaboration. Simultaneously, integrating visual literacy culture [7] aims to enhance students' ability to interpret, analyse, and create visual messages effectively, fostering their visual communication skills in an increasingly image-driven society. Illustrative learning media [19] complements these approaches by providing visual aids and representations that help clarify complex ideas, making learning more accessible and engaging for students with diverse learning styles and preferences. Together, these strategies enrich the high school curriculum, promoting comprehensive learning experiences that cater to the needs and interests of contemporary students.

Developing critical thinking skills at the vocational high school level through practical learning media has not been widely carried out. In general, learning media in the automotive sector that have been developed include distributor-less ignition, which presents ignition system components and electrical symbols and is suitable for facilitating students' learning [20]. The learning media for automotive power transfer systems is cutting, which shows the internal components and how they work, so it has been proven effective for use in learning [21]. Apart from that, using the Science, Technology, Engineering, and Mathematics (STEM) learning model in learning maintenance of power transfer systems has proven effective in improving the critical thinking abilities of automotive light vehicle engineering students [22]. Based on research that has been conducted, it has not yet led to the use of automotive engineering learning media in efforts to improve students' critical thinking abilities.

Using practical learning media combined with teaching methods or other media will support the development and increase student involvement in learning [23]. Therefore, vocational education needs to organise learning to develop critical thinking skills in students [24].

Students' critical thinking abilities can be developed by applying innovative methods and using appropriate learning tools. This effort aims to help students develop the ability to identify, analyse, conclude, and apply the learning process results [25]. Research conducted at SMKN 71 Jakarta shows that the learning media used by teachers affects students' critical thinking abilities [26]. Therefore, multimedia as an interactive learning medium has proven effective in improving the critical thinking skills of both male and female high school students in seeking truth, open-mindedness, analytical thinking, systematic thinking, and curiosity [25]. The learning carried out, especially in Vocational High Schools, does not fully implement learning that encourages students to master critical thinking skills. As learning occurs at Cendikia Bangsa Vocational School, where the forms and learning activities still use conventional methods, this condition causes students' critical thinking abilities to be low [27]. Research findings show that the critical thinking abilities of automotive engineering students are classified as deficient, and some are very deficient [28], as happened in East Java, where students' critical thinking abilities were 49.88% [29].

The low level of critical thinking ability is caused by teaching materials, characteristics and patterns of students' cognitive development, which have not been directed towards learning to think critically [30]. The learning process carried out at the observation location was observed to use a conventional approach. Even though they have used projector-assisted media, students appear passive in participating in the lesson. Teachers are too focused on delivering material rather than developing students' critical thinking skills [31]. Similar conditions were encountered during practical activities in the workshop; the teacher demonstrated how to maintain vehicles, and students listened and paid attention to the teacher. After observing, I noticed that not all students were allowed to try to practice directly. This condition is related to the limited availability and condition of practical materials and the teacher's ability to develop learning. Judging from the education reports obtained by this vocational school

in 2022, it was found that students' abilities in knowing, applying, and reasoning were only 52 to 54. This figure shows the need to improve the school's learning quality.

Students' critical thinking abilities can be instilled through practical activities and exercises consistently and slowly [14, 32] by implementing problem-solving ability-based learning [24], and the use of appropriate learning media supports critical thinking skills [28]. Learning media developed by teachers has been proven effective in improving students' critical thinking skills [33]. The portable multi-CDI DC motorbike ignition system trainer is an innovation developed to train vocational school students' critical thinking skills, especially in maintaining and repairing motorbike ignition systems. Combining four types of motorbike ignition systems from different manufacturers is hoped to provide students with practical learning experiences. It is especially related to the ability to identify the problems and evaluate the results of improvements to the motorbike ignition system as a series of critical thinking processes.

METHODS

Participants and Instruments. This research uses a development research (R&D) design with the ADDIE development model. The stages of developing the ADDIE model are identical to applying the products produced in learning, Where analysis becomes the basis for solving problems. The population of this study was 64 students in class XI of the Motorcycle Engineering and Business Skills Program. Sampling used a purposive sampling technique because there were limitations in the number of vocational school students who could be accessed or were relevant to the research topic. Thus, using purposive sampling makes it possible to maximise the use of resources by selecting participants who best represent the population under study. This research took place at a technology and engineering-based Vocational High School in Lunyuk Regency, West Nusa Tenggara Province, to implement the school's work plan to improve the learning process through the development and use of media in learning. The research stage begins with analysing learning problems and media needs using observation sheets, interview sheets, and documentation sheets.

The design stages are carried out by designing, creating a layout, identifying the need for tools and materials and developing measurement instruments. The development stage is done by making the box, installing components, and installing cables and power supplies. The validity test involved 2 teachers as material experts, 2 lecturers as media experts, and 15 students in the feasibility test. Participants in this research were vocational school students in the engineering and motorbike business fields, with an age range of around 16 to 18 years. They already have basic skills in motorcycle engineering, such as understanding the basic principles of engines and conventional ignition systems. These vocational school students were chosen because they are relevant to the research topic and have a clear interest in motorcycle engineering. They are also the main target of this research, which aims to improve the critical thinking skills of engineering and motorbike business vocational school students. This research involved two material experts and two teachers preparing the learning program. The first material expert is an experienced practitioner in motorcycle engineering, while the second material expert has a background in critical education or educational psychology.

Meanwhile, the two teachers involved are a motorbike engineering teacher at a vocational school and a professional education teacher with experience managing learning at vocational high schools. Their participation is important in planning, implementing, and disseminating learning programs to effectively achieve the objectives of this research. So that the discussion is more focused, this article only discusses the effectiveness test of the portable multi-CDI motorbike ignition trainer that was developed to improve student's critical thinking skills along with the findings in the testing process.

Testing effectiveness in the learning process uses a non-equivalent group pretest-posttest quasi-experiment design. The research respondents consisted of XI TBSM 1 as the experimental group and XI TBSM 2 as the control group. The experimental group was given treatment using a developed training trainer, while the control group received conventional learning (friendly and coercive) during the 2-month experimental period. After an experimental period of 2 months, testing was carried out to measure the effectiveness of each learning approach in improving the critical thinking abilities of engineering and mo-

torbike business vocational school students. To determine the trainer's effectiveness in improving students' critical thinking skills, a paired t-test was carried out between the pretest and post-test results. The following is the research design which was carried out:

Table 1 – Design Experiment

Class	Group	Pretest	Treatment	Post-test
XI TBSM 1	Experiment	Y1	Learning using	Y2
XI TBSM 2	Controls	Y2	A trainer who developed learning conventional	Y2

Table 2 – Indicator Think critical, which developed

System Indicator	Bicycle ignition motorcycle			
	Brand A	Brand B	Brand C	Brand D
Identify component system ignition	V	V	v	v
Explain the method of Work system ignition	V	V	v	v
Stringing system ignition	V	V	v	v
Diagnostics damage system ignition	V	V	v	v
Repair system ignition	V	V	v	v
Evaluate results of repair system ignition	V	V	v	v

Table 3 – Test Precondition Normality And Homogeneity

Test	Type Test	Results		Decision	Conclusion
Normality	Kolmogorov-Smirnov	Sig Class controls	= 0.129 = 0.200	> 0.05	Distribute Normal
Homogeneity	Lavene	Sig experimental class Sig	= 0.261	> 0.05	Homogeneous

Table 4 – Results Testing Effectiveness

Test	Testing	Mean	Results Df	Sig.2 Tailed	Decision	Conclusion
Test t paired	Pretest_Experiment → Posttest_Experiment	- 33,807	- 2,304	0,000	H ₀ rejected	Different significant
	Pretest_Control → Posttest_Control	- 28,495	- 3,613	0,000	H ₀ rejected	Different significant
Independent Samples t-test	Posttest_Experiment → Posttest Controls	74,432	2,324	0,000	H ₀ rejected	Different significant
	Pretest_Experiment → Pretest Controls	69,463 40,625 40,968	1,869 3,589 1,622	0,623	H ₀ accepted	No different significant
Test effect	Cohen's	D = 1.753	Category tall			

RESULTS AND DISCUSSION

The motorbike maintenance and repair field requires critical thinking skills to produce effective solutions and actions to overcome damage to motorbikes. The observation results show that students' critical thinking skills at the research location are medium. Teachers must develop learning media to improve students' critical thinking abilities [33]. To analyse the trainer's effectiveness in improving students' critical thinking skills, prerequisite tests were carried out in normality and homogeneity tests, followed by effectiveness tests.

Table 3 shows the results of prerequisite testing. Prerequisite tests are conducted to determine whether the data from trainer testing results can be continued for effectiveness testing.

The results of the normality test with Kolmogorov Smirnov show that the sig. control and experimental classes were 0.129 and 0.200 > 0.05. It can be concluded that the data from the control class and experimental class are normally distributed. Homogeneity testing uses the Lavene test with a sig result of 0.261 > 0.05, so it can be concluded that the data is in a homogeneous condition.

Table 4 shows the results of the t-paired test between the pretest and post-test results of the experimental group with sig. 2 tailed 0.000 < 0.05.

Based on the results of the pretest and post-test, there are differences in the critical thinking abilities of students in the experimental class and learning using the trainer that was developed. Likewise, the results of the t-paired t-test between the pretest and post-test results of the control group with sig results. 2 tailed $0.000 < 0.05$. This shows that there are also differences in critical thinking abilities based on the results of the pretest and post-test in the control class, which uses conventional learning. The research results also showed a mean difference between the experimental group's pretest results and the control group's pretest results, with results of 40.625 and 40.969. However, based on the results of sig. 2 tiles with a result of $0.623 > 0.05$, it is concluded that there is no significant difference in students' critical thinking abilities between the experimental group and the control group.

The independent sample t-test results showed that the mean post-test for the experimental group was 74.432, and the mean for the control group was 69.463. This shows a difference between the experimental and control groups' post-test results. Apart from that, the sig value. The two tails produced by these two groups were 0.000 and < 0.05 . Based on these results, it was concluded that there was a significant difference between the post-test results of the experimental group, which used a multi-CDI portable ignition system trainer in learning and the control class, which used conventional learning. The effect of using a multi-CDI portable ignition system trainer on improving students' critical thinking skills in learning was tested using Cohen's effect size test. Based on the test results, it is known that the Cohen SD value is 1.753, which shows that using a multi-CDI portable ignition system trainer has a big influence on increasing students' critical thinking abilities.

Virtual Reality technology integrated with the Portable Multi CDI Ignition System is designed to enhance students' critical thinking skills through interactive learning experiences. The system begins with sensors on the Portable Multi CDI Ignition System that collect technical data, such as voltage, current, and ignition frequency. This data is then sent to the processor and controller, which process and convert the data into a format compatible with the Virtual Reality device.

The results of this data processing are integrated into the Virtual Reality interface, which consists of a VR headset to display realistic simulations and interactive controllers as input tools for direct interaction. Students can interact with the CDI system simulation through this device, learn how it works, and perform various technical experiments. The system is equipped with a real-time feedback feature, which provides information in the form of visuals, audio, or analytical data related to the system's response to student interaction.

This process helps students deeply understand technical material and trains their critical thinking skills through simulation-based problem-solving and analysis. Teachers can also monitor student progress through the system's data, making it an effective tool for technology-based learning.

Increasing students' abilities in the attitudinal, cognitive and psychomotor domains indicates success in the learning process [34], where mastery of these three domains is closely related to mastery of critical thinking skills [35]. The findings of this research show that there has been a decline in the level of critical thinking abilities of vocational school students, where the level of critical thinking abilities in the control and experimental classes is lower compared to the previous year. The implications of these findings recommend that schools carry out evaluations and improvements to the learning process, especially creating an active, creative and innovative learning atmosphere by optimising the use of learning resources and triangulating objects [36]. The results of preliminary studies state that almost all learning activities at this vocational school still use a teacher-centred approach [37, 38]. Subject teachers dominate the explanation of the subject matter, both verbally and visually, using projectors or whiteboards [37, 39, 40, 41]. Practical learning, which should be filled with activities to identify components and carry out damage analysis and overlays, has been replaced with demonstration methods from the teacher [42, 43]. This method causes students to tend to be passive and unable to develop their potential [39]. Students only pay attention to demonstrations delivered by the teacher without being allowed to experience the learning process directly. This causes students' inability to master the concepts and technical skills they learn, especial-

ly during practical activities [42, 43]. After digging deeper, the decline in critical thinking skills is caused by using learning presentation methods that do not direct students to develop critical thinking skills and the availability of practice facilities that do not yet have sufficient carrying capacity in terms of number, technology and readiness [28, 30].

The low thinking ability of students is a phenomenon that occurs in almost every educational institution. According to [44], the critical thinking abilities of vocational school students are at the basic level. Meanwhile, authors [45] stated that students' critical thinking abilities in the evaluation, analysis and self-regulation sub-skills are relatively low. This low critical thinking ability is caused by internal and external factors [46]. Learning style tendencies are internal factors that can influence students' critical thinking abilities [47]. Meanwhile, student-centred learning is an external factor in improving critical thinking skills [48]. Student-centred learning can be realised if students actively participate in learning [23, 49–51]. According to previous research, the use of collaborative learning methods, such as technology and innovative learning media, is a real step in efforts to improve students' critical thinking abilities in learning activities [52–56].

Apart from that, using media in learning plays a role in improving critical thinking skills. According to [33], learning media developed by teachers has proven effective in improving students' critical thinking skills. Teachers are considered to know students' characteristics, conditions and learning needs [57]. Therefore, the media developed is very appropriate for use in learning [28]. The effectiveness testing results prove that using a multi-CDI portable ignition system trainer greatly influences the student's critical thinking skills in the experimental class. The use of media is one of the efforts of teachers to facilitate central learning for students [58]. Students are involved and actively participate in the learning process, so there is interaction between students and students and students and the learning media used. This interaction increases students' critical thinking abilities [59]. The interaction between students and the media is carried out by providing a stimulus through direct observation of the real components installed on the trainer (domain C1). These observations give rise to the skills of asking what, why and how [60]. In this context are the components' names, their function, and how they work (domain C2). Through

this process, students are encouraged to dig deeper [61] into constructing the four types of motorbike ignition systems presented by the trainer.

The cognitive level resulting from learning to use a multi-CDI portable motorbike ignition system trainer encourages students to apply previous knowledge (domain C3). Through small groups, students learn procedures for assembling ignition system components using connecting cables until the system works. In this condition, students are conditioned to problems that arise in real life [62] so that they can think multidimensionally [61] by integrating cognitive knowledge into psychomotor skills in Domain P2. Through multidimensional thinking, students are brought to develop scientific reasoning [63]. Multidimensional thinking directs students to think four steps ahead and is accompanied by additional dimensions of thinking. This multidimensional thinking begins with collecting various information, connecting cause and effect statements, and finding new meaning by reconciling previous knowledge to produce multifunctional and multi-tasking abilities [64]. Through this thinking process, students can analyse the errors that cause the ignition system circuit not to work.

Critical thinking skills are closely related to interactions in learning. Among them are interactions between students and learning facilitators, interactions between students and students and interactions between students and the media used in learning [65, 66]. Within the scope of this research, the interaction pattern students and the trainers used positively impacted their understanding of the material. They laid the foundation for cognitive mastery at the next level [67]. This aligns with Jean Piaget's cognitive development theory, which states that students' cognitive development depends on interaction patterns with the learning environment [68]. This interaction pattern will produce certain information to which students will respond in the form of assimilation, adaptation and equilibrium. The assimilation process occurs when the knowledge received follows students' cognitive structure. This knowledge is then adapted through a reconstruction process to form new knowledge. For this reconstruction process to run, there must be a balance (equilibrium) connecting new knowledge with the existing internal structure [68].

Good interaction between students and teachers will help students accept and process the new knowledge they receive. This aligns with Vygotsky's sociocultural theory regarding student development, stating that cognitive development occurs due to social interaction in the learning context [69]. There is a diversity of student characteristics in the learning process, which has implications for differences in speed in responding to stimuli [70]. This is where social interaction is needed in the learning process. Vygotsky divided the cognitive zone into the zone of actual development (ZAD) and the zone of proximal development (ZPD). Zone of actual development (ZAD) occurs when students can complete their work independently.

Meanwhile, the zone of proximal development (ZPD) occurs when students need help (scaffolding) from friends or teachers to solve their problems. This scaffolding causes interaction between students and teachers so that learning becomes interactive. This interaction allows students to explain their point of view regarding strategies and solutions to solve a problem [71].

Using problem-based learning methods and certain media has improved students' critical thinking abilities [72, 73]. Using a developed media trainer, the learning process is carried out by raising ignition system problems. This aims to train students to develop analytical and problem-solving skills [74, 75, 76]. Learning begins with the ignition system damage analysis stage. Learning at the analytical level is carried out through activities to diagnose ignition system damage. Damage diagnosis includes ignition system problems on four types of motorbikes. Students are placed in this condition's cognitive analysing and psychomotor (precision) domains.

As a group, students carry out the process of observing, measuring, analysing, concluding and implementing improvements according to the characteristics of the problems following standard operational procedures. This strategy aims to train students to develop critical thinking skills [77]. The domain of evaluation and articulation is defined through the ability of students to assess and decide on the results of repairing ignition system damage. In learning, students determine and ensure that the electrical voltage acting on the ignition system components and spark plugs is by specifications. At this stage, students are required to have analytical skills to decide the quality of their work. Creation and naturalisation

are achieved by providing opportunities for students to repeat the process of assembling, checking, diagnosing and testing independently. Learning skills through repeated experiments will positively impact improving students' skills [78, 79, 80], students with students and interactions between students and the media used in learning [65, 66]. Within the scope of this research, the interaction between students and the trainers has a positive impact on strengthening their understanding of the material and laying the foundation for cognitive mastery at the next level [67]. This aligns with Jean Piaget's cognitive development theory, which states that students' cognitive development depends on interaction patterns with the learning environment [68]. This interaction pattern will produce certain information to which students will respond in the form of assimilation, adaptation and equilibrium. The assimilation process occurs when the knowledge received follows students' cognitive structure. This knowledge is then adapted through a reconstruction process to form new knowledge. For this reconstruction process to run, there must be a balance (equilibrium) in connecting new knowledge with the existing internal structure [68].

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One unexpected finding was increased critical thinking skills in the control class that used conventional learning. This finding was also reported [81], who stated that conventional learning can improve critical thinking skills at a moderate level if it is done by linking learning content with students' daily lives. Conventional learning methods are generally carried out through explanation and demonstration, namely by presenting material accompanied by direct examples [82]. Several studies show that demonstration can increase students' knowledge [83, 84]. If designed well, demonstration learning can improve conceptual understanding, writing, planning and design skills closely related to 21st-century skills [85, 86]. Explanation and demon-

stration techniques are a teacher-centred learning approach. This technique can be combined with other learning models, including direct instruction or direct learning models. The direct instruction learning model emphasises efforts to facilitate students to master basic skill competencies through a step-by-step learning pattern based on predetermined stages [87]. In direct instruction learning, concept explanation or demonstration of motor skills is carried out to train motor skills through direct guidance and direction from the teacher or instructor. This aims to develop procedural skills through a declarative learning approach [88]. The declarative learning process is closely related to reinforcing expected behaviour. Based on behavioural learning theory, success in learning depends on providing teacher or instructor feedback [89]. Therefore, reinforcement at each stage of learning in direct instruction must be carried out to strengthen mastery of skills from each learning activity [90].

CONCLUSIONS

The critical thinking ability of vocational school students is alarming due to the use of learning methods and media that do not provide opportunities for developing critical thinking. The developed portable multi-CDI ignition system trainer has proven effective in improving the critical thinking skills of vocational school students in motorbike engineering skills programs. In achieving this, the interaction factor between students and the learning environment greatly influences the level of achievement of students' critical thinking skills. The research findings provide implications for improving critical thinking skills using student-based approaches, collaborative learning, problem-based learning, and repeated experiments or practicums to form students' psychomotor competencies. The scope of this research is limited to improving critical thinking abilities using the trainer that was developed. Hence, the effectiveness of increasing critical thinking in students' ability to solve ignition system problems on real motorbike units is unknown.

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