



Effectiveness of Matlab-based Learning and Thinking Styles (Internal-External) on Students' Higher Order Thinking Skills

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Renewal efforts in learning basic electricity and electronics in vocational high schools need to be carried out in order to find the right formula in learning as a new tool to improve students' higher-order thinking skills (HOTS). HOTS are in three dimensions of knowledge, namely conceptual, procedural, and metacognition, which intersect with cognitive levels C4 (analyse), C5 (evaluate), and C6 (create). This research is a quasi-experimental, nonequivalent control group design by applying Matlab application-based learning in the experimental class and comparing it with direct learning in the control class to see differences in students' higher-order thinking skills. In addition, it also looks at the interaction effect between the type of learning applied and the moderator variable, namely the thinking style of students (internal and external), on students' HOTS in three dimensions of knowledge (conceptual, procedural, and metacognition). The participants, or experimental subjects, in this study were class X students with audio-video engineering expertise (TAV). Class X TAV 1 was selected as the experimental class with 34 students, while class X TAV 2 became the control group with 32 students. The results obtained showed the effect of matrix-based learning better than direct learning on students' HOTS in the dimensions of conceptual knowledge, procedural knowledge, and metacognition, and there was no interaction between the type of learning applied and the students' thinking style. Matlab-based learning and thinking styles had a strong influence separately on students' HOTS in the three knowledge dimensions.

Keywords: matlab-based learning, thinking styles, internal, external, conceptual

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INTRODUCTION

In facing rapid and unpredictable changes in the future, vocational high school (VHS) students, as the millennial generation, need to develop higher-order thinking skills (HOTS) in order to create innovative and creative works (Novyanti et al., 2021). VHS's success in providing and supporting its students with HOTS will determine the school's status as a quality educational institution. According to Lewis and Smith (1993), since the time of prominent philosophers such as Socrates, Plato, and Aristotle, aspects of higher-order thinking skills (HOTS) have been researched in depth. HOTS enables students to solve problems by developing critical, creative, and analytical thinking skills towards information (Camellia et al., 2021; Prastyo et al., 2020). Newmann (1990) stated that HOTS provides greater challenges for students to interpret, analyze, and manipulate information. The strengthening of HOTS in VHS vocational study programs focuses on the application of concepts relevant to 21st century needs, technological literacy, as well as developing students' lives and training students in solving problems thoroughly and comprehensively (Rozi et al., 2021; Arfandi and Suryani, 2021). According to Budsankom et al. (2015), students' mastery of HOTS will enable them to create new knowledge and make appropriate and logical decisions amidst the development of information and technology. HOTS requires very deep thinking; therefore, it is categorized as "effortful" and also relates to psychological, physical, and experiential aspects that can be developed in the learning process to prepare students for the world of work (Hasan and Pardjono, 2019; Resnick, 1987). Byrnes (1991) classified HOTS into four levels, namely: 1) application level, 2) analysis level, 3) synthesis level, and 4) evaluation level. According to Anderson et al. (2001), the revised taxonomy contains a series of cognitive processes that show a higher level of complexity. The revision was conducted by incorporating the dimensions of factual knowledge, conceptual, procedural, and metacognitive. And HOTS is situated within the dimensions of conceptual, procedural, and metacognitive knowledge.

Literature Review

Conceptual, Procedural, and Metacognitive Knowledge

Conceptual knowledge includes several aspects, such as knowledge of classifications and categories, principles and generalizations, as well as theories, models, and structures (Practice & Bloom, 2008). Conceptual knowledge is one of the most important aspects of modern education and helps students transfer their acquired knowledge into a new context (Schoultz et al., 2001; Yusuf and Prabowo, 2019). Kilpatrick (2010) revealed that there are three measurements used to evaluate students' conceptual understanding, namely the ability to recognize the relationship between concepts, convey ideas clearly, and know the most appropriate representation of the situation. Procedural knowledge is an understanding of strategies, ways, or steps that need to be taken, i.e., knowledge of actions that must be taken to achieve various goals (Byrnes and Wasik, 1991; Conley, 1986; Hernando et al., 2013). In the context of roles in teams or groups, Banks and Millward (2007) state that procedural knowledge, in contrast, does not require team members to make inferences about each other's needs. Meanwhile, metacognition is a more advanced intellectual process in the learning

process, such as planning learning, applying appropriate skills and strategies to solve problems or tasks, making estimates regarding possible outcomes, and adjusting the range of learning (Coutinho, 2007; Herlanti et al., 2013; Herlanti et al., 2017). Metacognition consists of two interconnected elements, namely knowledge of understanding and management skills (Kuhn, 2000). (Kuhn, 2000). By using metacognition, students can develop their understanding of how to learn independently and improve their ability to transfer learning to new situations and events more effectively (Kim et al., 2013). Therefore, in VHS, teachers must guide students to master critical and creative thinking skills so that when they graduate, they are ready to face the challenges of the world of work in the era of industrial revolution 4.0 and life in the 21st century (Kurniawan et al., 2019; Dewanto et al., 2018).

Direct Learning

Teachers at the research school are currently using conventional learning in the form of direct learning. According to Mortella and Ausdemore (2005), in its implementation, the direct learning model can take the form of lectures, training demonstrations, or practical exercises, as well as collaboration in group work. Arends (2008) states that the direct learning model is a learning approach designed to improve students' understanding of procedural and declarative knowledge. In the classroom learning stage, students are generally grouped into small units and given the opportunity to respond either collectively or individually, accompanied by immediate feedback using specific correction steps (Shippen et al., 2005). In a more general teaching context, the teacher takes on the role of directing learning with a view to overcoming educational barriers faced by groups of students (Grossen, 2004). The application of direct learning methods is more suitable for students who have low motivation and face challenges in the learning process (Eggen and Kauchak, 2012).

Matlab-based Learning

In a vocational high school environment, teachers are faced with the need to become trainers and use computers as one of the innovative media in the form of software. The purpose of using this software is to arouse students' interest in learning and develop their expertise in practicum (Nur Cahyo and Wailanduw, 2016). Several studies have used software, including Matlab applications, both at the school and college levels. The results of these studies show an increase in concept understanding, both for students and university students, in the learning process.

Through the computational power of Matlab, students can cement their understanding of system concepts (Zhou, 2020). The results of research conducted by Hutagalung (2018) and Parinduri (2018) at the senior high school and vocational school levels show that the use of Matlab applications helps in modeling and simulating electrical circuits, such as voltage, current, and resistance, as well as compiling RLC circuit simulation models and aligning theory with the form of models and simulations implemented through Simulink in learning basic physics and basic electronics. Furthermore, according to Widiaty et al. (2019), teachers and students have the opportunity to improve a more holistic learning process through a digital approach, and one of the tools utilized is the Matlab application. Cretchley et al. (2000) stated that in the world of

education, Matlab software is very commonly used because it has special features that make it easier for students in terms of calculations and making graphs. In addition, according to Huang (2014), Matlab is used as a method of analysis and calculation in mechanical problems, which helps students understand the teaching content better and improve learning efficiency.

Thinking Style

According to Oflaz (2011), an individual's thinking style can determine the dominance of the brain owned by that person. The activities performed by individuals are the result of the dominance of the right brain and the left brain. For example, activities such as copying designs, drawing shapes, understanding geometric shapes, reading facial expressions, listening to music, and expressing feelings tend to be preferred by students who have right-brain dominance. Meanwhile, students who are more left-brain dominant will tend to focus more on language skills, have higher creativity, and tend to be used to analyzing. The theory of thinking styles is not a new concept in the scientific world. This concept was first introduced by Grigorenko and Sternberg through the term "mental-self government" (MSG), or the science of mental government that focuses on individual thinking styles. In this MSG theory, there is a metaphor that connects the way individuals organize their thoughts with the way society is organized (Moutsios-Rentzos and Simpson, 2014). Cilliers and Sternberg (2001) indicated that thinking styles refer to an individual's preferred approach to thinking, and if similar abilities exist in two or more people, then there is a high probability that their thinking styles will differ. Individual thinking styles tend to be flexible and not tied to rigid patterns. In the coverage aspect of the multidimensional thinking style theory, namely the internal and external dimensions, it is explained that individuals who have an internal thinking style tend to feel satisfied when engaged in tasks that allow them to work independently. In contrast, individuals with external thinking styles are more likely to favor participation in tasks that allow them to work collaboratively with others (Zhang & Sternberg, 2002).

Cognitive Learning Theory, Cognitive Load Theory, and Neuroplasticity Theory

Cognitive learning theory, cognitive load theory, and neuroplasticity theory are referenced in the context of Matlab-based learning in this study. Learning is a complex act of construction and reconstruction of knowledge other than the act of receiving and reproducing information. A child will construct their knowledge through a developmental process of adaptation, assimilation, and accommodation (Kincheloe, 2007). Children's interests, according to Piaget, are central to a child's mental activity to build knowledge and intelligence. These values are related to interactions with others and are the basis for new feelings, such as sympathy and antipathy, and moral values. (Devries, 1940). Cognitive development is a series of processes that run without certain stages, influenced by the learning process and the level of maturity of the child (Densinon et al., 1940). (Densinon et al., 2002). Because it involves the integration of new elements into previous frameworks and intelligence constantly adjusting those frameworks to match new elements, the process of assimilation is never entirely pristine (Lawton et al., 1980). According to Von Glasersfeld (1989), the constructivist view also underlines the significance of learning and knowledge in developing the subject's

cognitive balance. These values are related to interactions with other individuals and are the basis for the emergence of new feelings, such as sympathy and antipathy, as well as moral values. (Devries, 1940).

According to Piaget, the result of the processes of adaptation and assimilation is intelligence. All organisms adapt to their environment in order to survive. The main goal in designing Matlab-based learning materials is to reduce unnecessary cognitive load and instead increase the level of germane load so that learners can achieve the desired learning outcomes (Kruger & Doherty, 2016).

Cognitive load theory emphasizes the importance of reducing students' cognitive load so that they can focus more on understanding concepts rather than cognitive processes that are too heavy. While Demarin et al. (2014) explain that neuroplasticity refers to the brain's ability to change, restructure, and adjust in order to improve its abilities and adapt to unfamiliar situations,

Neuroplasticity theory states that the brain has the ability to change the structure and function of neural circuits in response to experience and learning. In Matlab application-based learning, repeated interactions with the software can lead to changes in neural connections in the brain, allowing students to improve their understanding of concepts related to the application.

Therefore, in this study, the implementation of Matlab application-based learning in basic electrical and electronic subjects in VHS is compared with direct learning, which is conventional learning that has been applied before. The aim is to see the difference in students' HOTS due to the implementation of the two lessons by considering the internal and external thinking styles of the students themselves.

METHOD

Type of Experiment

The type of experiment in this study is a quasi-experiment with the design type of nonequivalent control group design, which has treatments, outcome measures, and experimental units but does not use random placement. The participants, or experimental subjects, in this study were students from class X with audio-video engineering (TAV) expertise. Class X TAV 1 was selected as the experimental class consisting of 34 students, while class X TAV 2 became the control group consisting of 32 students. This study used a 2x2 factorial design, which means it consists of two factors, namely learning Basic Electricity and Electronics based on Matlab applications, and each factor has two categories, namely the internal thinking style and the external thinking style of students. By using this factorial design, the research can observe the effect of each independent variable individually and simultaneously on the dependent variable, as well as see the interactions that may occur between these variables. To analyze the data, the Multivariate Anova Analysis Technique, or MANOVA, was used with the help of IBM SPSS Statistics 22 software. There were two data collection techniques used, namely documentation and instrument tests.

Research Subject

This research was conducted at SMK Negeri 2 Kupang, Indonesia, in class X of Audio Video Engineering Expertise Competency (TAV). In this study, two parallel classes were selected, where class X TAV 1 became the experimental group and class X TAV 2 became the control group. All students who took Basic Electricity and Electronics became research subjects. Previously, the research subjects were given a pretest to assess the initial ability of both classes in the subject. The pretest results were statistically analyzed using the t test, and the research subjects were selected based on the criteria of homogeneous initial ability.

Research Variables

Figure 1 explains the relationship between the research variables, where the independent

variables and their effects are (1) Matlab application-based learning and (2) direct learning. The moderator variable is the thinking style of students who are in two categories, namely: (1) internal thinking style and (2) external thinking style, and the dependent variable is higher-order thinking skills (HOTS) in three dimensions of knowledge, namely: conceptual, procedural, and metacognitive.

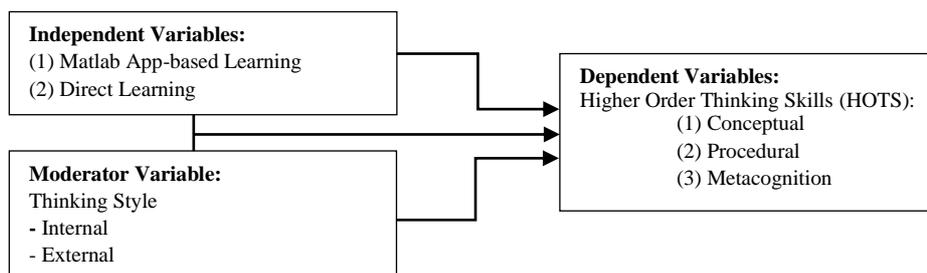


Figure 1
Relationship between Research Variables

Matlab-Based Learning

Simulink

In this model, students are taught to use Simulink in Matlab to understand the essence of the concepts of Ohm's law and Kirchoff's law in series, parallel, and mixed electrical circuits, not just by memorizing or knowing them passively. The focus is on actively involving students in seeing the phenomenon of current, voltage, and resistance relationships by applying simulations. The learning process begins with students observing the simulation and the resulting values, and then students assemble an understanding of the concept in their own words based on the results of the simulation. After that, students try to apply the concept independently and in groups. Students deeply understand the principle of Ohm's law, where the potential difference or voltage (V) is proportional to the current strength (I), as well as the relationship $R = V/I$ in Ohm's law. The learning process also includes a deeper understanding of Kirchoff's law

in series, parallel, and mixed circuits by simulating the properties of electrical circuits so that students can observe and provide arguments based on the results of the simulation.

Simulink is also used to simulate the basic gates of a digital circuit. In this lesson, students are given practice creating combination circuits from basic logic gates in stages. They first construct basic logic gates using Matlab and then input the results in the form of truth tables sequentially for each input and input combination. These skills are the foundation needed to solve more complex problems in electrical engineering.

Coding

In learning the concept of AC signal waves using simple coding from Matlab, The focus is on the basic elements of AC signals. The Matlab application-based learning approach gives students the opportunity to simulate the basic elements of a signal so that they can deeply understand the concepts of frequency, amplitude, period, and wavelength, which are the basis of an AC wave.

With a good understanding of this concept, students can better understand alternating current and then be able to apply it to the AC wave equation. This allows them to better solve problems related to AC wave parameters.

Thinking Style

The moderator variable in this study is based on Sternberg's Mental Self-Government (MSG) theory and consists of two dimensions, namely internal thinking style and external thinking style. To determine the distribution of students who have internal and external thinking styles, students were asked to fill out a questionnaire that had been validated by linguists. This questionnaire consists of 16 randomly arranged question items and covers aspects of internal and external thinking styles. The tendency of which thinking style the students have is taken from the highest average score they have in their questionnaire answers.

Overall, this study involved two groups of research subjects, namely the group with an internal thinking style of 28 students and the group with an external thinking style of 38 students, out of a total of 66 students. The complete distribution of students' thinking styles can be found in Table 1.

Table 1
Distribution of research subjects based on thinking style

Thinking Style	Number of Students	Percentage (%)
Internal	28	42,42
External	38	57,58
Total	66	100

FINDINGS

Statistical test results in Table 2 show that the mean scores for all HOTS learning outcomes, including conceptual, procedural, and metacognition, for the experimental class with Matlab-based learning are higher than the control class with direct learning.

Table 2
Statistical description of research data

Descriptive Statistics					
	Learning	ThinkingStyle	Mean	Std. Deviation	N
Conceptual_LO	Matlab-based Learning	Internal	75.4287	9.30942	15
		External	83.3079	10.42044	19
		Total	79.8318	10.57190	34
	Direct Learning	Internal	70.4400	12.39802	13
		External	75.2632	8.68523	19
		Total	73.3038	10.44477	32
	Total	Internal	73.1125	10.93950	28
		External	79.2855	10.30239	38
		Total	76.6667	10.93522	66
	Procedural_LO	Matlab-based Learning	Internal	77.0567	8.65501
External			81.3163	10.22336	19
Total			79.4371	9.66426	34
Direct Learning		Internal	70.8969	6.47690	13
		External	74.0784	12.75324	19
		Total	72.7859	10.63947	32
Total		Internal	74.1968	8.20202	28
		External	77.6974	11.97587	38
		Total	76.2123	10.61242	66
Metacognition_LO		Matlab-based Learning	Internal	74.33	7.037
	External		79.74	7.541	19
	Total		77.35	7.710	34
	Direct Learning	Internal	66.15	5.460	13
		External	75.79	6.294	19
		Total	71.87	7.594	32
	Total	Internal	70.54	7.496	28
		External	77.76	7.137	38
		Total	74.70	8.080	66

Table 2 shows that for conceptual knowledge, the mean score of the Matlab-based learning group is 79.83, which is higher than the mean score of the direct learning group, which is 73.30. The mean value for procedural knowledge of the student group taught with Matlab application-based learning is 79.43, which is also higher than the student group taught with direct learning, which is 72.78. As for the average value of metacognition knowledge of student groups taught with Matlab application-based learning, it is 77.35, higher than the student group taught with direct learning's value of 71.87.

The results of hypothesis testing using multivariate analysis are shown in Table 3.

Tabel 3
Multivariate test

Multivariate Tests ^a						
Effect		Value	F	Hypothesis df	Error df	Sig.
Intercept	Pillai's Trace	.994	3533.406 ^b	3.000	60.000	.000
	Wilks' Lambda	.006	3533.406 ^b	3.000	60.000	.000
	Hotelling's Trace	176.670	3533.406 ^b	3.000	60.000	.000
	Roy's Largest Root	176.670	3533.406 ^b	3.000	60.000	.000
Learning	Pillai's Trace	.235	6.159 ^b	3.000	60.000	.001
	Wilks' Lambda	.765	6.159 ^b	3.000	60.000	.001
	Hotelling's Trace	.308	6.159 ^b	3.000	60.000	.001
	Roy's Largest Root	.308	6.159 ^b	3.000	60.000	.001
Thinking Style	Pillai's Trace	.299	8.524 ^b	3.000	60.000	.000
	Wilks' Lambda	.701	8.524 ^b	3.000	60.000	.000
	Hotelling's Trace	.426	8.524 ^b	3.000	60.000	.000
	Roy's Largest Root	.426	8.524 ^b	3.000	60.000	.000
Learning * ThinkingStyle	Pillai's Trace	.038	.793 ^b	3.000	60.000	.502
	Wilks' Lambda	.962	.793 ^b	3.000	60.000	.502
	Hotelling's Trace	.040	.793 ^b	3.000	60.000	.502
	Roy's Largest Root	.040	.793 ^b	3.000	60.000	.502

a. Design: Intercept + Learning + ThinkingStyle + Learning * ThinkingStyle

b. Exact statistic

The explanation of the results obtained in Table 3 is as follows:

1. Simultaneous testing for both types of learning, obtained a significance value of $0.001 < 0.05$. This shows that there are significant differences in conceptual knowledge, procedural knowledge, and metacognition knowledge between students who follow Matlab application-based learning and students who follow direct learning together.
2. Simultaneous testing for both thinking styles owned by students, obtained a significance value of $0.000 < 0.05$. This shows that there are significant differences in conceptual knowledge, procedural knowledge, and metacognition knowledge between students who have internal thinking styles and students who have external thinking styles.
3. The interaction effect between applied learning and students' thinking style simultaneously obtained a significance value of $0.502 > 0.05$. This shows that there is no interaction effect between learning and thinking styles on conceptual, procedural, or metacognition knowledge.

The results of the MANOVA test for each variable are shown in Table 4.

Tabel 4
Test of between-subjects effects

Tests of Between-Subjects Effects						
Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	Conceptual_LO	1402.457 ^a	3	467.486	4.550	.006
	Procedural_LO	959.470 ^b	3	319.823	3.117	.032
	Metacognition_LO	1456.072 ^c	3	485.357	10.794	.000
Intercept	Conceptual_LO	372443.086	1	372443.086	3624.932	.000
	Procedural_LO	369777.514	1	369777.514	3604.153	.000
	Metacognition_LO	352111.584	1	352111.584	7830.686	.000
Learning	Conceptual_LO	682.611	1	682.611	6.644	.012
	Procedural_LO	721.296	1	721.296	7.030	.010
	Metacognition_LO	590.954	1	590.954	13.142	.001
ThinkingStyle	Conceptual_LO	648.377	1	648.377	6.311	.015
	Procedural_LO	222.504	1	222.504	2.169	.146
	Metacognition_LO	908.873	1	908.873	20.213	.000
Learning * ThinkingStyle	Conceptual_LO	37.530	1	37.530	.365	.548
	Procedural_LO	4.671	1	4.671	.046	.832
	Metacognition_LO	71.974	1	71.974	1.601	.211
Error	Conceptual_LO	6370.180	62	102.745		
	Procedural_LO	6361.053	62	102.598		
	Metacognition_LO	2787.868	62	44.966		
Total	Conceptual_LO	395705.970	66			
	Procedural_LO	390669.017	66			
	Metacognition_LO	372500.000	66			
Corrected Total	Conceptual_LO	7772.636	65			
	Procedural_LO	7320.523	65			
	Metacognition_LO	4243.939	65			

a. R Squared = .180 (Adjusted R Squared = .141)

b. R Squared = .131 (Adjusted R Squared = .089)

c. R Squared = .343 (Adjusted R Squared = .311)

LO = Learning Outcomes

The MANOVA test results for each variable in Table 4 show:

1. For conceptual knowledge of both types of learning, the probability significance value is less than 0.05, or $0.012 < 0.05$. Therefore, it can be interpreted that there is a significant difference in conceptual knowledge between students who learn with the Matlab application-based learning method and students who learn with the direct learning method.
2. For conceptual knowledge of both thinking styles, the probability significance value is less than 0.05, or $0.015 < 0.05$. Therefore, it can be interpreted that there is a significant difference in conceptual knowledge between students who have an internal thinking style and students who have an external thinking style.

3. For the interaction effect between learning and thinking styles on conceptual knowledge, the test results show a significance probability value of more than 0.05, or $0.548 > 0.05$. Therefore, it can be interpreted that there is no significant interaction effect between learning and thinking style on students' conceptual knowledge.
4. For procedural knowledge of both types of learning, the probability significance value is less than 0.05, or $0.010 < 0.05$. Therefore, it can be interpreted that there is a significant difference in procedural knowledge between students who learn with the Matlab application-based learning method and students who learn with the direct learning method.
5. For procedural knowledge of both thinking styles, the probability significance value is more than 0.05, or $0.146 > 0.05$. Therefore, it can be interpreted that there is no significant difference in procedural knowledge between students who have an internal thinking style and students who have an external thinking style.
6. For the interaction effect between learning and thinking style on procedural knowledge, the test results show a probability significance value of more than 0.05, or $0.832 > 0.05$. Therefore, it can be interpreted that there is no significant interaction effect between learning and thinking style on students' procedural knowledge.
7. For metacognition knowledge of both types of learning, the probability significance value is less than 0.05, or $0.001 < 0.05$. Therefore, it can be interpreted that there is a significant difference in metacognition knowledge between students who learn with the Matlab application-based learning method and students who learn with the direct learning method.
8. For metacognition knowledge of both thinking styles, the probability significance value is less than 0.05, or $0.000 < 0.05$. Therefore, it can be interpreted that there is a significant difference in metacognition knowledge between students who have an internal thinking style and students who have an external thinking style.
9. For the interaction effect between learning and thinking styles on metacognition knowledge, the test results show a probability significance value of more than 0.05, or $0.211 > 0.05$. Therefore, it can be interpreted that there is no significant interaction effect between learning and thinking style on students' metacognition HOTS.

DISCUSSION

The Effect of Matlab Application Based Learning vs. Direct Learning on Higher Order Thinking Skills (HOTS)

Students experience a deeper understanding of the concepts of Ohm's law, parallel and mixed series electrical circuits, AC signal wave characteristics, and digital circuits through Matlab application-based learning. This approach does not simply require students to memorize and know these concepts; it involves them actively in seeing the phenomenon of current, voltage, and resistance relationships through simulations with Matlab. Then, students observe the values that emerge from the simulation and formulate their own opinions about the concepts that occur, using their own words.

After that, they have the opportunity to try to apply the concept independently and collaborate with classmates.

The application of Matlab application-based learning in basic electrical and electronics subjects has shown positive results in its effect on conceptual knowledge, which is one of the dimensions of students' higher-order thinking skills (HOTS). Research by Han et al. (2011) is also in line with these findings, showing that the use of Matlab applications in practical teaching can help students deepen their understanding of concepts and theories. As a result, students' learning interest increases, which in turn allows them to better understand and apply their knowledge to deal with practical problems that may be encountered in real life.

Students from the Matlab application-based learning class group exhibited a very good ability to acquire procedural knowledge. Students can master the steps in finding the relationship between current strength and potential difference through simulation, the steps in applying Ohm's law, and the steps in determining the replacement resistance in an electrical circuit. They are also adept at assembling series, parallel, and mixed circuits and evaluating the properties of the circuits using Matlab applications. Students are able to measure current strength and change the values of voltage and resistance parameters in turn. Their skills also include the ability to create simple coding and algorithms to generate an AC signal using parameters such as amplitude, frequency, and phase. In addition, they can create combination circuits between basic logic gates in stages by first composing basic logic gates using Matlab and inputting them in the form of truth tables sequentially for each input and combination of inputs. All of these skills are very important foundations for solving more complex problems in electrical engineering.

These results are consistent with the recommendations of Nevaranta et al. (2019), who stated that the use of Matlab scripts can make learning more interactive and easily adopted by students as a new learning style in the field of control engineering.

This improves students' visual outcomes and also allows them to learn independently. The researchers recommended the use of Matlab in other interactive learning materials, as this application can provide significant benefits in improving students' understanding and their learning skills in electrical engineering.

Students with metacognitive skills have shown a good understanding of some basic electricity and electronics materials. They can explain well the reasons why series circuit installations are cheaper than parallel and mixed circuits and why the lights in series circuits are dimmer than in parallel circuits. In addition, they can also identify the advantages and disadvantages of series, parallel, and mixed circuits based on their knowledge of the concepts of current and voltage dividers. Their ability to visualize the generation of AC waves based on their knowledge of signal components and see the impact of changes in parameters such as frequency, amplitude, and phase also demonstrated good metacognition skills.

In learning logic circuits, students who have metacognitive ability can independently monitor their understanding by checking the extent to which they understand the basic

concepts of logic gates such as AND, OR, NOT, and others. They are also able to create truth tables and design combination circuits based on their knowledge of the input and output relationships of basic logic gates.

The development of metacognitive skills in vocational students has a positive impact on their learning experience and success in mastering basic electricity and electronics. Teachers and educators can play an important role in fostering these metacognition skills by explicitly teaching metacognitive strategies, providing opportunities for self-reflection, and encouraging students to play an active role in their learning process. Thus, students will be able to improve their learning skills and overall understanding.

Matlab-based learning uses visual displays of circuit components in Simulink and coding to enhance vocational students' brain responses to electricity and electronics concepts. The visualization of the components gives students a deeper understanding of the circuit elements, the quantities involved, and the meaning of the basic parameters in electricity and electronics.

This research shows conformity with Piaget's theory of cognitive learning, where students use their schemata to organize and combine knowledge gained from the learning environment when using Matlab applications. Piaget's theory highlights the importance of the processes of assimilation, which is connecting new information with existing schemata, and accommodation, which is adjusting schemata to accommodate new information. As students learn with the Matlab application, they can experience both of these processes when associating concepts they have learned with new features or adapting their understanding to understand new things. Piaget emphasized the importance of interaction with the environment in cognitive development. Matlab-based learning allows students to understand the basic concepts of electrical electronics better because they interact directly with the software. This is in line with Kincheloe's (2007) view that children construct knowledge through a process of adaptation, assimilation, and accommodation.

The use of Matlab applications in learning basic electricity and electronics clearly attracts high interest from students. With high interest, students in the experimental class seemed more enthusiastic about participating in learning. This phenomenon is consistent with Piaget's view that interest plays a central role in building students' knowledge and intelligence. Students at VHS organize their interests by forming a hierarchy of personal values, especially their interest in learning basic electricity and electronics because it is considered more interesting.

Matlab-based learning is also able to change teachers' views on students' cognitive balance. In this learning, students have the freedom to choose other solutions for constructing knowledge. Von Glasersfeld (1989) stated that teachers are motivated and supportive to create learning that suits students' accommodation needs, which means supporting the development of their conceptual network models.

From the viewpoint of cognitive load theory, Matlab-based learning uses interactive interfaces and visual aids that help reduce students' cognitive load by presenting information in a more structured and understandable manner. The design of Matlab-

based learning materials aims to reduce unnecessary burden, thereby increasing the level of understanding (Germane) to achieve the desired learning outcomes by learners (Kruger & Doherty, 2016).

Cognitive load theory emphasizes the importance of presenting information through an efficient cognitive processing process. In learning with Matlab, various visuals such as graphs and diagrams are used to present information in a clear and easy-to-understand manner, thereby reducing students' cognitive load when processing information. Sweller's cognitive load theory also highlights the importance of practice and deep understanding to strengthen information processing. Through Matlab-based learning, students can practice interactively through simulations, experiments, and tasks that apply the concepts learned. This approach helps students develop active skills when using Matlab.

Neuroplasticity theory is another approach that explains the advantages of learning with Matlab. Neuroplasticity describes the brain's ability to change and adapt throughout life. According to Demarin et al. (2014), neuroplasticity can be defined as the brain's ability to change, remodel, and reorganize itself to achieve better capabilities and adapt to new situations. This means that the human brain can change the connections between its nerve cells in response to experience, learning, and practice.

In the context of classroom learning, the use of Matlab applications as tools has successfully increased students' engagement, motivation, and interaction with the subject matter. When students engage in intense and focused learning by using Matlab applications, their brains undergo structural and functional changes that affect the connections between nerve cells. The theory of neuroplasticity becomes a key concept in shaping students' skills and abilities, which is the basis of all neuropedagogy. Knowledge acquisition occurs at the human psycho-physiological level, with complex skill formation at the neural level, i.e., the neurons of the human brain (Kolomiets et al., 2020).

Learning aids such as Matlab applications provide additional stimulation for students' brains. Research on the brain and neuroplasticity also shows that as learning progresses, nerve cells in the brain will develop additional nerve fibers (dendrites) and synapses. Learners improve their physiological neural networks through active exploration and experimentation (Smilkstein, 1991). The attention given by students to doing simulations with Matlab shows that this learning increases their focus on solving problems.

In linking teaching and the brain, Masson & Foisy (2014) state that attention is the most important concept. The teaching process directs learners' focus so that it affects their brain attention during the learning process. Neuroplasticity theory asserts that attention is a key concept in linking teaching and brain learning. This is not only relevant in education and neuroscience, but also because research shows that when a teacher directs students' attention during the learning process, it affects the way the brain works to complete tasks and develop new abilities.

The Effect of Internal Thinking Style and External Thinking Style on Higher Order Thinking Skills (HOTS)

The external thinking style describes individuals who focus more on external stimuli and feedback to process information. They tend to prefer collaborative learning environments, enjoy group discussions, and seek external sources of knowledge and guidance. External thinkers are good at networking, collaborating, and applying knowledge in real-world situations.

VHS students with external thinking styles actively participate in collaborative environments. They like to work with classmates or others, share ideas, and discuss concepts. Feedback from peers and teachers is important to them, and they tend to communicate their thoughts and ideas verbally. In learning basic electricity and electronics, students with an external thinking style often engage in discussions, ask questions, and like group activities. They are more inclined towards hands-on experience and practical application of knowledge, thus excelling in vocational learning with collaborative characteristics in problem solving.

Meanwhile, the internal thinking style refers to the internal processing of information by individuals who tend to be more introspective. They engage in reflective thinking, analyze situations in depth, and have strong self-awareness. These traits are beneficial in situations such as studying complex subjects or engaging in tasks that require careful analysis and attention to detail. Internal thinkers excel in independent research, critical thinking, and introspective activities.

The results showed that VHS students with external thinking styles were more favorable to learning basic electricity and electronics in terms of conceptual knowledge and metacognition, but there was no significant difference in procedural knowledge. The differences in conceptual and metacognitive knowledge between students' internal and external thinking styles can be explained as follows:

Students with an internal thinking style are more likely to use an introspective and reflective approach to acquiring conceptual knowledge. They engage in internal mental processes, such as making connections, relating new information to prior knowledge, and developing a deep understanding of concepts. On the other hand, students with external thinking styles rely more on visual aids and other external representations to understand concepts. They benefit from real examples and hands-on activities to strengthen their conceptual understanding.

For metacognition knowledge, students with an internal thinking style tend to have a higher level of self-awareness. They engage in self-reflection, self-questioning, and monitoring their own thinking. They realize their cognitive strengths and weaknesses, understand learning preferences, and apply strategies accordingly. On the other hand, students with external thinking styles externalize their thinking, explain their reasoning verbally, and seek feedback from others to improve their understanding of metacognition.

It is important to create a balanced learning environment that caters to both thinking styles to improve student engagement, learning outcomes, and overall success in vocational high school. Students can develop the ability to adapt and utilize their unique thinking styles in various learning situations.

The Effect of Interaction between Learning and Thinking Styles on Higher Order Thinking Skills (*HOTS*)

The absence of interaction between learning type and thinking style based on the results of the study indicates that both variables, namely learning type (Matlab application-based learning or direct learning) and thinking style (internal or external), have an equally strong influence on the dependent variable, namely higher order thinking skills (*HOTS*) in the conceptual, procedural, and metacognition dimensions.

The results of statistical tests indicate several things, namely: (1) Matlab application-based learning is superior to direct learning in improving higher-order thinking skills in conceptual, procedural, and metacognition dimensions, both for students who have internal thinking styles and students who have external thinking styles; and (2) students who have external thinking styles have higher average scores than students who have internal thinking styles in all learning outcomes, both conceptual, procedural, and metacognition. (3) The application of Matlab application-based learning is more effective in improving higher-order thinking skills in conceptual, procedural, and metacognition dimensions among vocational students, regardless of students' thinking styles. In other words, matrix-based learning is more effective in improving the higher-order thinking skills (*HOTS*) of vocational students in various dimensions, and the results do not depend on students' thinking styles.

The extent of the influence of the moderator variable of thinking style on students' *HOTS* is seen from the average score of conceptual, procedural, and metacognition learning outcomes between students who have an internal thinking style and students who have an external thinking style, where the external thinking style is higher than the internal thinking style. This result is found in both groups of students: students with Matlab application-based learning and students with direct learning. Or, in other words, external thinking style has a better influence on student learning outcomes in conceptual, procedural, and metacognition dimensions compared to internal thinking style for both classes.

This result is in line with what was said by Olszewski et al. (2010): people who have an external thinking style tend to be extroverted, people-oriented, more outgoing, and more conscious interpersonal than internalists. They will look for problems that involve other people and like to work together to solve these problems, which encourages them to achieve better *HOTS* learning outcomes. Meanwhile, students with an internal thinking style, according to Sternberg (1997), do not feel happy to learn in groups or cooperate with other students in solving problems; this is what allows the achievement of *HOTS* learning outcomes to be lower than those of externalist students. Students with externalized thinking styles really like working with others and learn better in small working groups than when they are left to themselves (Sternberg, 1997).

Thus, it can be said that the independent variable, namely Matlab application-based learning, separately has a *main effect* on *HOTS* in the dimensions of conceptual knowledge, procedural knowledge, and metacognition of students. This is in line with what was revealed by Hutagalung (2018), Okoye (2010), and Zhang (2011). Yaz (1997) and Fangohr (2004) say that in the field of electronics and electricity, the calculation of the formulation of electricity, current, voltage, and power, as well as the development of system models and simulations, can be done using the Matlab program. Students with limited or no Matlab programming skills have a small investment of time to gain a better understanding of a subject with the help of interactive simulation instructors in solving electrical problems and their extensions through the utilization of Matlab as a renewable application so as to eventually find solutions to problems about modern electronic and communication technology. Using the Matlab application can improve the quality of teaching in vocational orientation and even reveal the interactive side of Matlab.

CONCLUSIONS

Based on the results of this study, it can be concluded that the use of Matlab application-based learning has a positive impact on students' *HOTS* in the dimensions of conceptual knowledge, procedural knowledge, and metacognition. Learning with the Matlab application stimulates students to think more critically, analyze information, connect concepts with the real world, and develop creative solutions in problem solving. These *HOTS* skills are important to develop deep understanding and complex thinking skills.

The use of Matlab as a learning tool also increases students' motivation and engagement in the learning process. This application provides an interactive and practical environment to learn electricity and electronics concepts in a more visual and applicable way, so that students can be more involved and interact with the subject matter. The external thinking style in this learning is superior to the internal thinking style because the characteristics of this learning demand more teamwork. However, it is important to note that the success of Matlab-based learning does not depend on students' thinking styles. Both have the same impact on students' *HOTS* ability.

The results of this study have positive implications for the use of technology in learning basic electricity and electronics. The use of a Matlab application can be an effective strategy to improve students' *HOTS* abilities and prepare them to face more complex problem-solving challenges in the future.

Therefore, to improve the higher-order thinking skills of vocational students, a teacher must pay attention to the characteristics of the lessons taught and adjust them to the right type of learning in order to improve student learning outcomes. The results showed a difference in students' *HOTS* skills based on the type of learning applied, but there was no interaction between the type of learning and the students' thinking style. In this context, it can be concluded that Matlab application-based learning is superior to direct learning, and this superiority does not depend on the thinking style of students in vocational high school.

As a suggestion for further research, it can be done by comparing Matlab-based learning with other learning models and looking at other variables that might moderate this independent variable on students' HOTS.

REFERENCES

- Anderson, L. W., Krathwohl, D. R., Airasian, P. W., Cruikshank, K. A., Mayer, R. E., Pintrich, P. R., Raths, J., & Wittrock, M. C. (2001). *Bridged Editio a Foit , and Editors*. <https://www.pdfdrive.com/a-taxonomy-for-learning-teaching-and-assessing-a-revision-of-blooms-taxonomy-of-educational-objectives-d187836328.html>
- Arends, R.I. 2008, *Learning to Teach*, Translation by Helly P.S. dan Sri Mulyantini S. Yogyakarta: Pustaka pelajar
- Arfandi, A., & Suryani, H. (2021). *The Ability of Vocational High School Teachers to Developing HOTS Question*. 3(3), 1–6.
- Banks, A. P., & Millward, L. J. (2007). Differentiating Knowledge in Teams: The Effect of Shared Declarative and Procedural Knowledge on Team Performance. *Group Dynamics*, 11(2), 95–106. <https://doi.org/10.1037/1089-2699.11.2.95>
- Budsankom, P., Sawangboon, Tatsirin Damrongpanit, S., & Chuensirimongkol, J. (2015). Factors affecting higher order thinking skills of students: A meta-analytic structural equation modeling study. *Academic Journals*, 10(19). <https://doi.org/10.5897/ERR2015>
- Byrnes, J. P., & Wasik, B. A. (1991). Role of Conceptual Knowledge in Mathematical Procedural Learning. *Developmental Psychology*, 27(5), 777–786. <https://doi.org/10.1037/0012-1649.27.5.777>
- Camellia, G. F., Hartono, & Ridlo, S. (2021). The development of HOTS-oriented science supplement book to improve problem solving ability of vocational school students. *Journal of Innovative Science Education*, 10(1), 314–318.
- Cilliers, C., & Sternberg, R. (2001). Thinking styles: implications for optimising learning and teaching in university education. *South African Journal of Higher Education*, 15(1), 13–24. <https://doi.org/10.4314/sajhe.v15i1.25375>
- Conley, K. M. (1986). Studying Knowledge Acquisition: Distinctions among Procedural, Conceptual and Logical Knowledge. *Annual Meeting of the Americal Educational Research Association (67th, San Francisco, CA, April 16-20, 1986)*, 1–35.
- Coutinho, S. A. (2007). The relationship between goals, metacognition, and academic success. *Educate~*, 7(1), 39–47. <http://educatejournal.org/index.php/educate/article/view/116>
- Cretchley, P., Harman, C., Ellerton, N., & Fogarty, G. (2000). MATLAB in early undergraduate mathematics: An investigation into the effects of scientific software on learning. *Mathematics Education Research Journal*, 12(3), 219–233. <https://doi.org/10.1007/BF03217086>

- Densinon, N., Copy Availaire, B., & Desna, A. (2002). *Reproductions supplied by EDRS are the best that can be made from the original document. mIDMIXOMING COMAGIUM U* (Issue 9). <https://files.eric.ed.gov/fulltext/ED357698.pdf>
- Devries, R. (1940). *Piaget 's Social Theory*. 26(2), 4–17.
- Dewanto, W. K., Agustianto, K., & Sari, B. E. (2018). Developing thinking skill system for modelling creative thinking and critical thinking of vocational high school student. *Journal of Physics: Conference Series*, 953(1), 0–6. <https://doi.org/10.1088/1742-6596/953/1/012115>
- Eggen, K. & Kauchak, D. 2012. *Strategie and Models for Teachers*. Sixth Edition. Terjemahan oleh: Satrio Wahono. Jakarta: PT. Indeks.
- Grossen, B. (2004). *Success of a direct instruction model at a secondary level school with high-risk students. Reading and Writing Quarterly*, 20(2), 161–178. <https://doi.org/10.1080/10573560490262091>
- Han, B., Zhang, C., & Qin, X. (2011). *Based on MAT LAB Signals and Systems Course Project-driven Teaching Method Xuefeng Qin*. 166–169.
- Hasan, A., & Pardjono, P. (2019). The Correlation of Higher Order Thinking Skills and Work Readiness of Vocational High School Students. *Jurnal Pendidikan Teknologi Dan Kejuruan*, 25(1), 52–61. <https://doi.org/10.21831/jptk.v25i1.19118>
- Herlanti, Y., Mardiaty, Y., Wahyuningtyas, R., Mahardini, E., Iqbal, M., & Sofyan, A. (2017). *Jurnal Pendidikan IPA Indonesia Metacognitive Knowledge on Biology Learning In Secondary School* 6(1), 179–186. <https://doi.org/10.15294/jpii.v6i1.9605>
- Hernando, M., Guzmán, E., & Conejo, R. (2013). Measuring procedural knowledge in problem solving environments with item response theory. *Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, 7926 LNAI, 653–656. https://doi.org/10.1007/978-3-642-39112-5_81
- Huang, D. (2014). The application of MATLAB in higher vocational engineering mechanics teaching. *Advanced Materials Research*, 889–890, 1667–1671. <https://doi.org/10.4028/www.scientific.net/AMR.889-890.1667>
- Hutagalung, S. N. (2018). Menggunakan Aplikasi Matlab Metode Simulink. *Journal of Science and Social Research*, 4307(February), 30–35
- Kim, Y. R., Park, M. S., Moore, T. J., & Varma, S. (2013). Multiple levels of metacognition and their elicitation through complex problem-solving tasks. *Journal of Mathematical Behavior*, 32(3), 377–396.
- Kilpatrick, J. (2010). Helping Children Learn Mathematics. In *Academic Emergency Medicine* (Vol. 17, Issue 12). <ftp://129.132.148.131/EMIS/journals/ZDM/zdm026r1.pdf>

- Kincheloe, J. L. (2007). The Praeger Handbook of Education and Psychology. *Reference Reviews*, 21(8), 20–21. <https://doi.org/10.1108/09504120710838787>
- Kolomiiets, A., Kraievska, O., Krupskyi, Y., Tiytiynnyk, O., Klieopa, I., & Kalashnikov, I. (2020). Formation of the Cognitive Component of Professionally-Oriented Mathematical Competence of Future Radio Specialists in the Context of Neuroplasticity of the Human Brain. *Brain. Broad Research in Artificial Intelligence and Neuroscience*, 11(3), 15–28. <https://doi.org/10.18662/brain/11.3/106>
- Kruger, J. L., & Doherty, S. (2016). Measuring cognitive load in the presence of educational video: Towards a multimodal methodology. *Australasian Journal*
- Krulik, S., & Rudnick, J. A. (1988). Problem Solving: A Handbook for Elementary School Teachers. In *Africa's potential for the ecological intensification of agriculture*.
- Kuhn, D. (2000). Metacognitive development. *Current Directions in Psychological Science*, 9(5), 178–181. <https://doi.org/10.1111/1467-8721.00088>
- Kurniawan, E., Muslim, S., Rahmadyanti, E., Aribowo, W., Kusumawati, N., Ismayati, E., & Basuki, I. (2019). 4 . 0 and the demands of life in the 21st Century Skills. 1(1), 40–52.
- Lawton, J. T., Saunders, R. A., & Muhs, P. (1980). Theories of piaget, bruner, and ausubel: Explications and implications. *Journal of Genetic Psychology*, 136(1), 121–136. <https://doi.org/10.1080/00221325.1980.10534102>
- Lewis, A., & Smith, D. (1993). Defining Higher Order Thinking. *Theory Into Practice*, 32(3), 131–137. <https://doi.org/10.1080/00405849309543588>
- Mortella, N.M. & Ausdemore, K. 2005. An Overview of Direct Instruction. Department of Counseling. Educational and developmental Psychology (CEDP).
- Moutsios-Rentzos, A., & Simpson, A. (2014). Durham Research Online Woodlands. *Critical Studies on Security*, 2(2), 210–222.
- Novyanti, Y., Rahmayanti, H., Azwar, S. A., Ichsan, I. Z., Singh, C. K. S., Rahman, M. M., Darussyamsu, R., & Ali, A. (2021). An Overview of Students' HOTS to Develop Instructional Kit for Disaster Mitigation based on Vocational Education. *Tadris: Jurnal Keguruan Dan Ilmu Tarbiyah*, 6(1), 117–124. <https://doi.org/10.24042/tadris.v6i1.8689>
- Nevaranta, N., Jaatinen, P., Grasbeck, K., & Pyrhonen, O. (2019). Interactive learning material for control engineering education using matlab live scripts. *IEEE International Conference on Industrial Informatics (INDIN)*, 2019-July(August 2021), 1150–1154.
- Newmann, F. M. (1990). Higher order thinking in teaching social studies: A rationale for the assessment of classroom thoughtfulness. *Journal of Curriculum Studies*, 22(1), 41–56.
- Nur Cahyo, T., & Wailanduw, A. G. (2016). Pengembangan Software Simulasi Trainer Sistem Penerangan Pada Mata Diklat Pemeliharaan Kelistrikan Kendaraan Ringan

Teknik Kendaraan Ringan VHS Negeri 7 Surabaya. *JPTM*, 05 nomor 1, 64–71.

Oflaz, M. (2011). The effect of right and left brain dominance in language learning. *Procedia - Social and Behavioral Sciences*, 15, 1507–1513. <https://doi.org/10.1016/j.sbspro.2011.03.320>

Parinduri, I. (2018). Model Dan Simulasi Rangkaian RLC Menggunakan Output Simulink. *Journal of Science and Social Research*, 1(1), 42–47.

Practice, T., & Bloom, R. (2008). A Revision of Bloom ' s Taxonomy : An Overview David R . Krathwohl. *ReVision*, 41(4), 212–218.

Prastyo, A. B., Gembong, S., Masfingatin, T., & Maharani, S. (2020). HOTS Android-Based student worksheets to practice creative thinking ability of vocational school students. *Journal of Physics: Conference Series*, 1464(1). <https://doi.org/10.1088/1742-6596/1464/1/012006>

Resnick, L. B. (1987). *Education and Learning to Think*. National Academy Press

Rozi, A., Khoiri, A., Dewi Mutia Farida, R., Sunarsi, D., Jasmani, Paeno, Munawaroh, & Iswadi, U. (2021). The fullness of Higher Order Thinking Skills (HOTS) in Applied Science Textbooks of Vocational Schools. *Journal of Physics: Conference Series*, 1764(1). <https://doi.org/10.1088/1742-6596/1764/1/012143>

Schoultz, J., Säljö, R., & Wyndhamn, J. (2001). Conceptual Knowledge in talk and text: What does it take to understand a science question? *Instructional Science*, 29(3), 213–236. <https://doi.org/10.1023/A:1017586614763>

Shippen, M. E., Houchins, D. E., Steventon, C., & Sartor, D. (2005). A comparison of two direct instruction reading programs for urban middle school students. *Remedial and Special Education*, 26(3), 175–182. <https://doi.org/10.1177/07419325050260030501>

Vida Demarin, Sandra Morovic, & Raphael Bene2. (2014). Demarin et al., 2014 Neuroplasticity. *Periodicum Biologorum*, 116(2), 209–211.

Von Glasersfeld, E. (1989). Cognition, construction of knowledge, and teaching. *Synthese*, 80(1), 121–140. <https://doi.org/10.1007/BF00869951>

Widiaty, I., Riza, L. S., Ana, Abdullah, A. G., Abdullah, M., & Mubaroq, S. R. (2019). Web-based digital learning application of iconic batik in batik learning at vocational high school. *Journal of Engineering Science and Technology*, 14(5), 2475–2484.

Yusuf, M., & Prabowo, P. (2019). Model Assesmen Pengetahuan Konseptual Mahasiswa Dalam Memecahkan Masalah Hukum Ohm. *Jambura Physics Journal*, 1(1), 41–58. <https://doi.org/10.34312/jpj.v1i1.2393>

Zhang, L. F., & Sternberg, R. J. (2002). Thinking styles and teachers' characteristics. *International Journal of Psychology*, 37(1), 3–12. <https://doi.org/10.1080/00207590143000171>

Zhou, Y. (2020). Research on Simulation Teaching of Communication System in

Higher Vocational Education Based on MATLAB. *Journal of Physics: Conference Series*, 1648(4). <https://doi.org/10.1088/1742-6596/1648/4/042008>