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Evaluation of Learning Cycle 4E-RE to Improve Chemistry Learning of Vocational High School Students

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Abstract: This study aimed to examine the effect of the Learning Cycle 4E-RE on the vocational school students' chemistry learning outcomes in light vehicle engine maintenance subject. The research subjects were 164 Vocational High School (SMK) students majoring in Technology and Engineering, the Automotive Engineering expertise program, consisting of 100 students in the experimental group and 64 students in the control group. The research instrument was a learning outcome test with 30 multiple-choice items with reliability of Kuder-Richardson ρ (KR 20) = 0.837. This study used a quasi-experimental pre / posttest control group design. The mean similarity of the experimental class and the control class was tested from the pretest results using t-test statistical analysis. The research hypothesis was tested using the ANCOVA test with a significance level of 5% (0.05). The results showed that there were differences in the learning outcomes of students who were taught with the Learning Cycle 4E-RE strategy with students who were taught with verification/conventional teaching. Student learning outcomes in the experimental class were higher than those in the control class. The implication of this research is that contextual learning strategies such as the Learning Cycle 4E-RE are suitable for vocational students to improve their learning outcomes. For further research, reflection activities in a learning strategy need to be tested again using different learning strategies and chemistry topics.

Keywords: Outcome assessment, learning strategies, vocational education, light vehicle systems

1. Introduction

Learning at the vocational high school (VHS) level in many countries, including Indonesia, has different characteristics from senior high schools (SHS). Yong-Jing (2010) and Guo (2011) stated that the characteristics of vocational education in China were to produce competitive products in the world of work, while high school graduates were projected to master theoretical knowledge. Likewise, with vocational learning in Germany, vocational students had characteristics as graduates who had high mobility in the world of work, had collaboration skills, and were able to adapt to the development of industrialization (Brauns, 1998; Weber & Achtenhagen, 2017). Meanwhile, vocational school learning in Australia had a similar characteristic, which was preparing graduates to be ready in the industrial world (Wheelahan, 2016). In short, the characteristics of vocational learning in those countries have the same thing in common, that is, work skills orientation.

The characteristic of vocational education in Indonesia directed students to develop skills following certain fields of work to create jobs (Budiastuti, 2014; Thamrin, 2014). This characteristic was manifested in the Indonesian mission of vocational education which prepared students to 1) be able to become a productive and professional workforce following the needs of the business world and industry; 2) create employment independently; 3) master science and technology so that students are able to adapt to modern work and life; and 4) be able to improve themselves continuously (Permendikbud, 2014; Ketelaar Beijaard, Boshuizen, and Den Brok, 2012). This mission could be achieved if the subjects at school were adjusted to the needs of the work field and student characteristics. Therefore, vocational education focused on promoting the transition between school activities and the world of work (Hanushek, Schwerdt, Woessmann, and Zhang, 2017).

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In vocational school learning in Indonesia, efforts to transition and fulfillment of the mission of vocational education experienced many gaps, especially in the learning aspect. As an illustration of these gaps were (1) vocational education in Indonesia, the world of schools, wanted graduates to have high learning achievement in a fast time while the industrial world wanted graduates with adequate technical competence and attitudes (Wibowo, 2016); (2) learning inVHS did not yet have a national standard that required adjustment to the dynamics of life that develops in the community. The learning method often used in classrooms was teacher-centered so that students were not given the freedom to develop their knowledge, creativity, and ability to create a work (Atika, Sudana, and Basyirun, 2017); (3) students were not yet ready to be demanded to adjust quickly to new technologies in the world of work with more complex problems related to daily life (Mohamad, 2017). To bridge this gap, more innovative learning strategies were needed with appropriate learning activities and teaching materials. So, learning in VHS should have had the characteristics that differentiate it from learning in SHS.

The gap in VHS had an impact on students' difficulties in understanding learning in one of the science subjects, chemistry, which was directed at work products. The chemistry learning process at VHS was strived to involve students actively in the work process and chemical scientific practice directly so that it was expected to produce learning outcomes that reflected the characteristics of vocational students. The difficulties were mainly in understanding chemical concepts and algorithmic calculations (Nisa, 2016) and making connections between macroscopic, submicroscopic, and symbolic representations followed by the students' inability to use the knowledge that had been acquired into new information or problems given (Rickey & Stacy, 2000). The possible difficulties experienced by students were because 1) there was a lack of synergy between chemistry learning content (adaptive) and vocational content in the automotive (productive) field to suit students' needs (Quinn & Safranski, 2018); 2) most of the teaching materials used in VHS were not up to standard in balancing productive content with adaptive content (Herawati & Suyahya, 2019). VHS students became less interested in learning chemistry as a result of the lack of a learning process that can reflect understanding chemistry into real-world problems.

This research was conducted as an effort to overcome the problem of lack of synergy in adaptive and productive learning by designing contextual learning that can accommodate both. In contextual learning, the introduction of a concept is based on the context previously known by students by providing real problems from everyday life. According to Bennet & Holman (2002), a chemistry curriculum that used contextual applications in the science-technology-society field will build a comprehensive understanding of science. The results of the study by Nentwig, Demuth, Parchmann, Grasel, and Ralle (2007) reported that contextual learning turned out to make students understand what chemistry was used for, to improve the process and learning outcomes of low-group students, and to eliminate the concerns of low-group students to learn independently. One of the contextual learning strategies in this study, which was considered to accommodate the need for contextualization of knowledge into real-world problems, was the 4E-Reflection-E Learning Cycle (LC 4E-RE).

This LC 4E-RE learning strategy was designed using constructivist and inquiry learning theories by referring to the 5E Learning Cycle steps (Bybee, Carlson-Powell, and Trowbridge, 2008), consisting of engagement, exploration, explanation, elaboration, and evaluation. Modifications were made by adding Reflection (R) between elaboration and evaluation so that it created LC 4E-RE learning stages which consisted of engagement, exploration, explanation, elaboration, reflection, and evaluation. The implementation of this strategy was expected to be able to facilitate students in relating chemical and automotive concepts more comprehensively with the help of reflection activities. For example, in learning the topic of gasoline, students were allowed to reflect on their chemical understanding at the reflection stage. Reflection on understanding is carried out by providing direct examples like the data of receipts for the purchase of premium, pertalite, and pertamax fuel which was compared in terms of the emission results. The efforts of reflection in the form of chemistry learning activities with real-world contexts can form a more connected student understanding (Middlecamp, 2018).

The addition of a reflection phase to the implementation of the LC-5E strategy was an innovative effort that was raised based on the results of Bard's research (2014: 1) which stated that reflection activities can facilitate a deeper understanding of concepts, systematically thinking, more organized data collection and analysis, and more comprehensive connection of concept with reality. Reflection learning is also able to combine competence with knowledge, skills, and attitudes (de Jong, 2019: 9). By doing reflection, students see what they have mastered from the lessons they have learned. Reflection is a cognitive process in the context of learning that is passed from experience. The reflection process will go through several stages: experiencing, interpreting what is experienced, explaining the problems or questions that have been experienced, and looking for answers. Students are asked to remember and understand the things they have learned. If there are things they realize they have not understood, they are asked to read again, ask their friends or teachers, and find sources from other books. Reflection will strengthen the knowledge gained by engaging students to study concepts in-depth and also to gain complex knowledge that is more accessible and usable. Students must do self-monitoring, self-regulating, and self-assessing (Leijen, Valtna, Leijen, and Pedaste, 2012).

Learning with this innovative strategy was expected to synergize adaptive and productive learning so that students' understanding of concepts can be improved. This study aimed to test whether the implementation of the LC 4E-RE learning strategy affects the chemistry learning outcomes of engineering technology vocational students.

2. Method

The research design used was a quasi-experimental (pre-test and post-test control group) design to test the effect of the LC 4E-RE learning strategy applied to students majoring in technology in the subject of Light Vehicle Engine Maintenance on students' chemistry learning outcomes. The research design was chosen because we are not able to random the subject individually. We only used the existing groups in the school where this study was conducted. There were two variables in this research, namely, independent and dependent variables. The independent variable is the learning strategy. On the other hand, the dependent variable is the students' learning outcomes. The control variables are the teachers, the time allocation for doing the teaching and learning process, and the administered teaching topics in the form of student worksheets. The topics taught were gasoline fuel, global warming, voltaic cells, electrolysis cells, and corrosion. The topics selected were contextual in that they related to students' real life. The research design was presented in Table 1.

Table 1 - Research design of quasi-experimental pre-post-test control group design

Group	*Pretest*	Treatment	*Post-test*
Experimental	*O*	*X*	*O*
Control	*O*	-	*O*

(Source: Fraenkel & Wallen, 2009:271)

Note:
X = LC 4E-RE learning strategy
O = learning outcomes test

The research subjects were students of grade X at two public vocational high schools in Malang majoring in Technology and Engineering: Automotive Engineering in the light vehicle engineering program. Each school had randomly selected control and experimental classes. The total number of control groups were 2 classes (N = 64), and the experimental groups were 3 classes (N = 100). The group selection is based on the similarity of the average scores obtained on the previous exam. The research was carried out in the academic year of 2018/2019 with 5 times face-to-face meetings, each contains the control and experimental groups. The chemistry topics taught were gasoline, global warming, voltaic cells, electrolysis cell, and corrosion. Two teachers participated voluntarily in the research. Each of the teachers taught the control class and the experimental class. Before teaching the class, teachers were given a short training on how to teach chemistry topics by applying LC 4E-RE steps using a teaching process that had been designed by the researchers. The two teachers applied conventional strategies that were not much different. The learning activities were carried out by giving lectures, classroom discussions, and laboratory verification practices. Researchers observed the whole learning activities to see their appropriateness with the learning scenario.

The treatment instrument was a teaching material in a form of a student worksheet. Meanwhile, the measurement instrument consisted of tests for measuring the students learning outcomes. The two instruments were validated by two experts: (1) chemistry education lecturers in higher education and (2) three teachers who had experiences in teaching chemistry. The examples of reflection activities in the worksheets can be seen in Figure 1. Besides, the learning steps can be seen in Table 2. The learning outcome instrument was a learning achievement test consisting of 30 multiple choice questions to measure the students' understandings of the topic of light vehicle engine maintenance. The instrument was developed by the researchers. It consisted of 6 items on each topic being taught (five topics). The competence of each item was focused on the competence at the vocational school level. Before giving the test, it was assessed by the validators in the contexts of the representativeness of the concepts of the study, the appropriateness of the components of learning outcomes, and the appropriateness of the language used in each item of the question. After trying out the test on 231 VHS students majoring in Technology and Engineering, the Kuder-Richardson 20 reliability (ρ KR 20) was found to be 0.837.

REFLECTION ACTIVITY

You have studied the types of fuel, the combustion system in the engine, and the impact of exhaust gases from combustion. Make a reflection on your understanding of the emission test results below!

a) How is the content of CO_2 and Hydrocarbons (HC) contained in Pertamax gasoline when compared to Pertalite and Premium gasoline?
b) What factors can cause a difference in the content of the two gases?
c) What impact does the high concentration of CO_2 and HC have on the environment?
d) How is the CO gas content found in Pertamax gasoline when compared to Pertalite and premium gasoline?
e) What are the consequences of having a high concentration of CO on human health?

Fig. 1 - Reflection activity of LC 4E-RE worksheet

Table 2 - Steps in strategy of LC 4E-RE and conventional

LC 4E-RE	Conventional
Engagement: consisted of building interest in the activity to be carried out, arousing curiosity, and connecting students with their initial knowledge. At this stage, a real phenomenon that was directly related to what was going to be studied was given to attract students' interest.	**Inform**: The process of providing information and transferring knowledge from teachers to students through lectures. At this stage, students got knowledge that was transferred directly from the teacher without any effort to construct independent understanding.
Exploration: consisted of observations; designing experiments; collecting, examining, and analyzing data or information. At this stage, students explored and understood texts in the given worksheets.	**Verification**: proving knowledge through laboratory activities, demonstrations, or video observations. At this stage, students verified the knowledge that came from the teacher's lecture through video observation activities.
Explanation: organizing the results of the analysis of the information at the exploration stage into the concept to be introduced. At this stage, students explained and constructed the concepts that had been obtained during the exploration stage.	**Conclusion**: concluding the learning activity. At this stage, students summarized and concluded the learning outcomes.
Elaboration: using the knowledge that had been built into new situations. At this stage, the students worked on routine exercises or new questions that had never been encountered before.	
Reflection: Reflecting on understanding by linking the acquisition of concepts to phenomena introduced at the beginning of learning or related new phenomena. At this stage, students answered deeper questions by being given new phenomena related to the material being studied.	
Evaluation: validating the learning results and summarizing the understanding obtained. At this stage, students summarized and concluded the learning outcomes.	

3. Results

To determine the similarity of the initial abilities of the control and experimental classes, the mean similarity test was carried out on the pre-test scores. The average similarity test was performed using the independent sample t-test. Both tests were carried out with the help of SPSS Statistics 24.0. The results of the analysis on the average similarity test showed that the control and experimental classes obtained 1.361, with a table value of 2.000 (df = 231). It can be concluded that there was no difference in pretest scores between the control and experimental class. Thus, both classes could be used as a control and experimental classes in research.

To determine the effect of LC 4E-RE on student learning outcomes, a two-way analysis of variance (ANCOVA) test was performed. This test was based on the result of the pretest as a variance (covariate) which represents students' prior knowledge. This variance can automatically affect students' learning outcomes. Two-way hypothesis testing of variance was done using the ANCOVA statistic at the 95% confidence level ($\alpha = 0.05$) through the IBM SPSS 24.0. ANCOVA examines the differences of two or more groups in one dependent variable. This analysis was used to eliminate or reduce noise in data analysis caused by other variables other than the variables under study. So, the effects can be seen clearly. The ANCOVA analysis results on students' learning outcomes showed that the F-count was 2.135. With the F-table of 1.93, the F-count was higher than F-table ($F_{count} > F_{table}$). Thus, the results of the two-way analysis of variance (ANCOVA) test showed that there were significant differences in learning outcomes between students in the experiment and students in the control class. This showed that the LC 4E-RE learning model influences students' learning outcomes. The students' learning outcomes in the experimental class were higher with an average score of 77.97, while in the control class the average score was 69.45. The statistical output results can be seen in Table 3 and Table 4. Interpretation of the statistic can be seen in Table 5.

Table 3 - Descriptive Statistics

Aspect	Mean Scores		95% Confidence Interval			
	Expt Group	Ctrl Group	Expt Group		Ctrl Group	
			Upper	Lower	Upper	Lower
Learning Outcomes	71,62	59,94	13,32	10,04	13,04	10,11

Table 4 - Quantitative Results Summary

Aspect	Mean scores			
	Expt Group	Ctrl Group	F	t
Learning Outcomes	71,62	59,94	(1.93)	14,08

Table 5 - ANCOVA Test Results On Students' Learning Outcomes

H_0	**Statistic test**	**Testing Criteria**	**F-Table**	**F-count**	**Test results**	**Conclusion**
H_0 = there is no difference in the learning outcomes of control and experimental class students with the same knowledge	*ANCOVA*	H_0 rejected if $F_{count} > F_{table}$	1.93 ($\alpha = 0.05$, df = 100	2.135	$F_{count} < F_{table}$	H_0 = rejected

4. Discussion

Vocational Education is an educational program designed to support Human Resources (HR) for the mastery of certain expertise or fields. The distinctive features of Vocational Education are the focus of learning for increasing students' ability in certain fields. On the era of the Indonesia Industrial Revolution 4.0, the needs for graduates of Vocational Education who have integrity are high. There are several revitalizations that will be carried out by the Ministry of Education and Culture. One of them is to sharpen the curriculum that is more needed by the industry. To prepare the students who meet industry demands and have the integrity, training is needed according to the required standards. Furthermore, sharpening the curriculum is the right choice to make the quality of vocational education increasingly needed by the industrial market. This revitalization begins by providing meaningful learning experiences for students, especially for science topics such as chemistry. The materials should be presented contextually so that it will improve the interest of the learners in learning. One of the efforts to contextualize chemical materials is to design the LC 4E-RE learning model which has been carried out in this study.

The results of statistical analysis showed that students taught using LC 4E-RE achieved better in learning outcomes with an average score of 71.62 than those who taught by using conventional learning with an average score of 59.94. The results of this study can be explained from several aspects explored during the application of teaching materials with LC 4E-RE. First, the students who were taught using LC 4E-RE produced more complete understandings than those who were taught by using conventional approaches. In LC 4E-RE learning, students took a series of inquiry activities before constructing knowledge. A series of inquiry activities listed in the learning phases produced complete understanding construction. For example, in the global warming subtopic, the students could be instructed to explore real phenomena in the form of carbon dioxide emission which was linked to the increase in the earth's temperature. The process of interpreting data or graphics was an intellectual activity that could affect the acquisition of concepts and had an impact on learning outcomes. The additional reflection phase also triggered students to reconcile the concepts that had been obtained with the phenomena given at the engagement stage so that students gained a more meaningful understanding. The results of the study were in line with Kipnis and Hofstein (2008) which stated that in inquiry-based learning, students realized that the steps taken must lead to conclusions in the form of knowledge, concepts, or principles. Middlecamp (2018) added that the learning process is associated with searching real-world reflection which can improve students' learning outcomes and thinking skills.

Second, students who were taught by using the LC 4E-RE strategy produced an applicative understanding compared to the students who were taught by using conventional approaches. In LC 4E-RE learning, students were given stimulants in the form of questions in the elaboration stage of the application of concepts and knowledge. The concepts had been obtained in new situations. This stimulant required students to provide logical reasons why the combination of concepts and knowledge that had been constructed previously could be integrated to solve the problem. Intellectual activity to access the most needed concepts and strategies in certain situations was an indicator of an applicable understanding of LC 4E-RE. The result of the study was in line with Kipnis and Hofstein (2008) who reported that in LC 4E-RE, data analysis activities triggered the students' creative thinking because the students were able to apply their knowledge to new questions found in other scientific fields. Besides, reflection activities in inquiry learning can train the students' analytical thinking skills (Han, Li, Sin, and Sin, 2018).

Third, students who were taught by using LC 4E-RE produced more reflective understandings than students who were taught using conventional strategy. In LC 4E-RE learning, concept acquisition was obtained from a series of intellectual activities carried out directly by students. After obtaining the concept. The students reflected on the problems presented at the beginning of the lesson. Reflection activity created a psychological meaning in the structure of students' thoughts. The knowledge obtained from the inquiry activity combined with the reflection process made the students felt easier for the recalling process and declaring the complete and informative knowledge content. If the students were impressed by the knowledge obtained during the reflection process, this knowledge will be easy to be recalled from long-

term memory. In line with Rodriguez and Towns (2019), reflection activity could trigger the connections of knowledge in students' minds.

The difference between the students' understandings in the LC 4E-RE and conventional classes were the main factors to differentiate the differences in learning outcomes. Comprehensive, applicable, and reflective understanding of the concept made it easier for students to solve the problems and produce a higher average score. In addition to the factors above, there were psychological aspects that affected the students' understandings. Students who are taught by using LC 4E-RE achieve better in obtaining knowledge by thinking independently. On the other hand, the students in the conventional class only obtain knowledge through passive transfer. Psychologically, the acquisition of knowledge independently could improve the students' memory retention. Good memory retention made it easier for the students to recall knowledge that had been obtained into a statement. It was used to answer the questions. This is in line with Suardana, Redhana, Sudiatmika, and Selamat (2018) that the students who are targeted to understand the concepts in conventional learning will limit students' retention in declaring their creative ideas. Based on the results of the research, the conclusion that can be used for future research purposes is in similar fields but on different chemical topics. Thus, differences in the result of the research can be invetigated after carrying out on abstract chemical topics such as atomic structure or chemical bonds.

5. Conclusion

The results of this research have implications that: (1) The learning process of light vehicle engine maintenance in vocational high school students should involve the contextualization of science and real-world situation because many students have not been trained to face the problems by linking science contextually; (2) The learning process of light vehicle machines maintenance should be carried out using an approach that triggers the students' intellectual activity in a systematic scientific methodology. In this case, LC 4E-RE is very recommended, and (3) The reflection activities should be done in the learning process by using different learning strategies and topics. So, the students have a vision and knowledge mastered for the future. As a result, the students feel very confident to solve the real world-problems later.

The implementation of LC 4E-RE for vocational students in light vehicle engine maintenance subjects influenced the learning outcomes. There was a difference between the learning outcomes of the students who are taught by using LC 4E-RE and the students who are taught by using conventional teaching. The learning outcomes of the students who are taught by the LC 4E-RE were higher than the learning outcomes of the students who are taught conventionally. This can be caused by the existence of deeper learning on LC 4E-RE in the form of giving real problems at the beginning of the learning. As an example, in-depth exploration that connects macroscopic and sub-microscopic aspects, and reflections used to test students' concept acquisition.

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