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The Effectiveness of E-Module on Buffer Solutions to Improve Students' Higher-Order Thinking Skills and Self-Regulated Learning

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Abstract

This study aims to determine the difference between Higher Order Thinking Skills (HOTS) and Students Self Regulated Learning (SRL) before and after using e-module based on the 7E (elicit, engage, explore, explain, elaborate, evaluate, and extend) learning cycle on the buffer solution material, and to determine the percentage of its effectiveness. The research use a quasi experiment with one-group pretest-posttest design. The subjects of this research were students of natural science 11^{th} grade in one of senior high schools in Yogyakarta. The instrument used were test in the form of HOTS pretest-posttest description question and non-test in the form of self-regulated learning questionnaire. The data analysis technique used is Hotteling's T^2 test. The results showed that the significance value was 0.000 < = 0.05, then H_0 was rejected. There were differences in students' HOTS and SRL before and after using e-module based on the 7E learning cycle. The effectiveness of using e-module show by HOTS and SRL simultaneously (36.8%), HOTS (25.2%), and SRL (20.5%).

Keywords: buffer solution, e-module, HOTS, learning cycle 7E, self-regulated learning

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1. Introduction

Nowadays, we are facing a problem with the emergence of Covid-19. The disease emerges in Wuhan, China, and surprisingly spreads rapidly to China and the whole world (Wickramasinghe et al., 2020). The dissemination of coronavirus disease has arrived in Indonesia and influenced many sectors, especially education. The government in every country must decide to close schools to cut the live chain of Covid-19 (Aji, 2020). As a result, the teaching-learning process that usually occurs in school now must be done at home. The result of research by Sintema (2020) revealed that Covid-19 has a bad influence on the education sector. One of the influence was deficient in e-learning facilitation used to interact with teachers and students.

Nowadays, teachers are demanded to create a new learning strategy using technology in the teaching-learning process in which it can be applied in pandemic condition through online/ long distance learning (Saraswati et al., 2019). The use of technology in the teaching-learning process can be applied through a technology-based teaching media (Açişli et al., 2011; Warburton, 2003). Teaching media is an education's scaffolding that can be used in the teaching-learning process to increase the effectiveness and the efficiency in reaching the aim of the teaching-learning process (Sanaky, 2013). A technology that is suitably used in the Covid-19 pandemic is the electronic module

(e-module). An e-module is a printed medium changed into a new module used technology (Voithofer, 2005).

Learning media can be collaborated with learning models to obtain more optimal results (Istuningsih et al., 2018). Especially now that Indonesian education refers to the 2013 curriculum, which demands learner-centered learning through a scientific approach (Kemendikbud, 2018). One model can be applied in the learning process with a scientific approach is the 7E learning cycle model (Sornsakda et al., 2009). The 7E learning cycle model uses constructivism theory which requires students to be active during the learning process (Balta & Sarac, 2016).

Many researchers have studied the learning cycle 7E model and have shown that learning using the learning cycle can improve students' critical thinking skills, conceptual understanding, and learning outcomes (Hardiansyah et al., 2013; Balta & Sarac, 2016). However, because the learning cycle 7E model takes a long time, many schools continue to use conventional teacher-centered methods in the learning process (Istuningsih et al., 2018). As a result, student learning activities decrease and impact the common understanding of basic concepts and student learning outcomes (Istuningsih et al., 2018).

Education nowadays enters the globalization era in the 21st-century and is faced with more complex challenges toward the education system in the world. According to UNESCO (2009), many skills that must be mastered in 21st-century, there are creativity and innovation, critical thinking and problem solving, communication and collaboration. An effort that must be made to run education challenges in 21st-century is a HOTS (Sahin et al., 2014).

Brookhart (2010) explained the HOTS in three categorizations, there are (1) Higher order thinking as a knowledge transfer; (2) Higher order thinking as the ability to have the critical thinking; and (3) Higher order thinking as an ability to solve problem. HOTS is a skill to have a high-order thinking level that relates to understanding students' fundamental concepts (Tacoshi & Fernandez, 2014). However, some research defines that weak mastering of the fundamental concept still becomes a general problem for chemistry students (Cooper et al., 2010; Burrows & Mooring, 2015). The weakness toward mastering the chemistry concept will make students less motivated to learn the next chemistry topic (Celikten et al., 2012).

The development of HOTS in the teaching and learning process refers to the 2013 curriculum which is an improvement from the previous curriculum. According to Bloom's taxonomy (1956), HOTS is higher-order thinking based on the newest revision model (Othman et al., 2015; Anderson & Krathwohl, 2001). Therefore, chemistry teachers should strengthen their fundamental ability and develop HOTS of students in the teaching-learning process at school in the framework of developing students' skills at solving chemistry HOTS problems based (Harta et al., 2020). On the contrary, it may be difficult because some chemistry teachers still lack the knowledge to stimulate students' HOTS (Fernandez et al., 2013; Azraai & Talib, 2015). Thus, the students' analysis skill in solving chemistry task-based higher-order thinking category is still weak (Harta et al., 2020).

Students commonly use HOTS to control knowledge, focus on responsibility, and to have a SRL (Paris & Paris, 2001; Brookhart, 2010). Hendrian et al. (2017) defined SRL and habitual learning are essential factors influencing HOTS. Experts of education agree that SRL is the most important factor in academic motivation and academic achievement (Zumbrunn et al., 2011). Hence, the fact-based on Zimmerman (1990) explained that the SRL of students still shows less with the low of academic achievement. Students with good SRL can set their learning style, initiative to search for information, search for solve barriers, and be more responsible (Zimmerman, 1990). Because of that, if students can solve higher-order thinking skill tasks, thus it can be said that they have a good SRL.

Complex material comes with many concepts, calculations, and applications in daily life. Hence, the buffer solution is perceivable at a lower cognitive level and needs analysis, evaluation, and creativity to master the concepts (Hardinita & Muchlis, 2015). Students that want to understand buffer solutions should master macroscopic, microscopic, and symbolic (Maratusholihah et al., 2017). The concept which becomes pre-conditions study of buffer solution is chemical equilibrium and acid/base concept (Bilgin & Geban, 2006). The result of Orgill and Sutherland (2008) research, show that students find it difficult to relate to the concept of buffer solution as follow, students tend to focus on macroscopic; students can identify that buffer belongs to either acid or base but they cannot relate the relationship between acid and base conjugation; and students find difficult to determine factors that are influence the buffer capacity.

The aims of this research are to know the difference and effectiveness of HOTS and SRL of students independently before and after using an e-module based on the learning-cycle 7E in buffer solution concept at senior high school.

2. Research Method

2.1. Research Design

The methode used in the research is quasi experiment with one-group pretest-posttest design. This research was conducted from March to April 2021. Research data was collected by conducting an online/distance learning process. The research design can be seen in Figure 1 and Table 1.

2.2. Sampling

The sample of this study amounted to 70 students from the 11th grade of Natural Sciences in one of the high schools in Yogyakarta. The sampling technique of this research is simple random sampling. The random sampling is a technique of randomly selecting samples from a specified population which each member of the population has an equal probability of being chosen. It is also meant to be an unbiased representation of a group of population. Before using questionnaires, empirical validation was carried out with the number of respondents for the HOTS questions pretest as many as 102 students and posttest as many as 124 students. While the empirical test for the SRL questionnaire amounted to 66 students.

2.3. Techniques and Instruments

Data collection techniques used in the form of test and non-test techniques. The test technique is in the form of questions of HOTS, which include pretest and posttest, while the non-test technique is in the form of a SRL questionnaire for students.

HOTS questions are arranged based on cognitive levels C4-C6, analyzing; evaluating; and creating five questions for the pretest and the posttest. Meanwhile, this SRL Instrument was prepared by adapting and developing from Zimmerman (1989) and Wolters et al. (2009). The number of statements in the SRL questionnaire is 24 using a four point likert scale.

2.4. Data Analysis Technique

2.4.1. Validity and Reliability Test

All of the instruments made must be through validation test and rehabilitation before being used in the research. The validation tests validation theory and empiric.

The validation theory done by expert judgement toward the set teaching equipment, HOTS questions, and questionnaire of SRL. The result of the validation theory is qualitative data such as suggestions or advice toward HOTS questions and SRL questionnaire. The suggestion given by expert judgement taken as a foundation to repair the teaching equipment, the HOTS questions and the questionnaire of SRL of students. The validation theory is used to set the products that will be developed have had good content or not (Aiken, 1999).

After revision has been done, the next step is empirical validation with a trial HOTS questions and questionnaire of students' SRL besides the research samples. Empirical tests

toward HOTS questions are pretest and posttest questions with 120 test respondents of students and posttest with 124 students. Hence, the empirical test toward questionnaire of SRL is 66 students. The empirical test results were done using the Rasch model's Quest program.

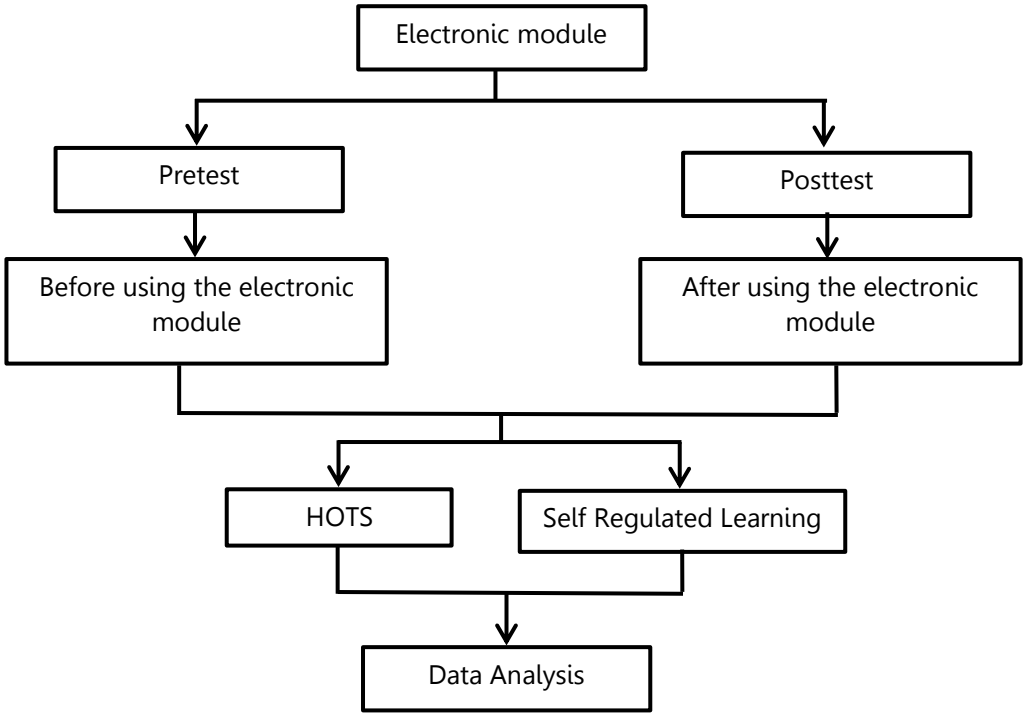

Figure 1. Research Design

Table 1. One-Group Pretest-Posttest Design

Pretest	Treatment	Posttest
O_1, P_1	X	O_2, P_2

* O_1 = Pretest HOTS; O_2 = Posttest HOTS; P_1 = SRL Questionnaire (Pretest); P_2 = SRL Questionnaire (Posttest); and X = Treatment.

Reliability is a coefficient that shows the level of consistency of the measurement results of a test. The estimation of the reliability of the questions according to the IRT (Item Response Theory) analysis can be known based on the item separation index (item estimate) and person separation index (case estimate). The criteria for item estimate and case estimate values can be seen in Table 2 (Smith, 2005).

Table 2. Criteria for Item Estimate and Case Estimate

No	Value	Category
1	< 0.67	Deficient
2	0.67 – 0.80	Average
3	0.81 – 0.90	Good
4	0.91 – 0.94	Very Good
5	>0.94	Excellent

2.4.2. Research Data Analysis

The data analysis technique used in Hotelling's T^2 test was carried out with the help of SPSS 16.0. The analysis can be done to meet the need of nine pre-qualification assumption tests of MANOVA, which are (1) the independent variable consists of two or more independent groups; (2) The dependent variable must be measured at the interval or ratio level; (3) there is no relationship between

observers within each group or between groups; (4) an adequate sample size of at least 25; (5) no univariate or multivariate outliers; (6) there is multivariate normality; (7) there is a linear relationship between each pair of dependent variables for each independent variable; (8) there is homogeneity can be seen from the Box's M test; and (9) there is no multicollinearity by looking at the Tolerance and VIF values, if the Tolerance value > 0.10 and VIF < 10, then the data is free from multicollinearity symptoms.

2.4.2.1. Multivariate Test

Multivariate test is Hotelling's T^2 test. Hotelling's T^2 test was used to analyze the difference between HOTS and SRL before and after using the e-module with learning cycle 7E.

2.4.2.2. Univariate Test

Univariate test is a between-subject effect test used to know every difference of HOTS and SRL of students before and after using an e-module on the learning cycle 7E in buffer solution concept.

Thus, the effectivity contribution percentage of e-module on the learning cycle 7E toward HOTS and SRL can be done by the help of SPSS with searching for the partial eta squared and multiple it by 100%.

3. Result and Discussion

The research using Google Meet, Whatsapp Group, and Google Form at SMAN 7 Yogyakarta. Google Meet is used when the teaching-learning process and Whatsapp Group are done to give information related to the teaching-learning process. Hence, Google Form was used to take the pretest and posttest data with supervision through Google Meet. The data taken by the research is quantitative of HOTS and SRL of students' scores. The test aims to know the differences between HOTS and SRL of students simultaneously and independently before and after use the e-module on the learning cycle 7E in buffer solution concept and to know the effectivity contribution given.

3.1. Validity and Reliability Test

All of the instruments, either HOTS questions (pretest and posttest) or SRL questionnaires, were done. The empirical test involved 102 students toward pretest, 124 students toward posttest, and 66 students toward SRL questionnaire. The result of the empirical test was then counted in the Quest program to know the validity and reliability of every question. The question is valid when infit MNSQ and outfit MNSQ in every question reveals appropriate Partial Credit Model. The questions are valid when the value is between infit MNSQ 0.77 until 1.33 and the outfit MNSQ between 0.5 until 1.5 (Adam & Khoo, 1996; Boone et al., 2014). The empirical test result for SRL can be seen in Table 3.

Table 3 show that HOTS questions for pretest and posttest are infit MNSQ area with the value of 0.77 until 1.33 and the outfit MNSQ in the value of 0.5 until 1.5. So, it can be concluded that pretest questions consisting of five questions and posttest consisting of six questions are valid, and all questions can be used in collecting research data. The empirical test results for the students' SRL questionnaire can be seen in Table 4.

Table 3. Infit MNSQ and Outfit MNSQ Value on the Pretest and Posttest Items

Test	HOTS Pretest		HOTS Posttest	
Number	Infit MNSQ	Outfit MNSQ	Infit MNSQ	Outfit MNSQ
1	0.90	0.87	0.99	0.84
2	1.10	1.33	0.86	0.87
3	0.81	0.90	1.01	1.43
4	1.01	1.02	0.86	0.89
5	0.80	1.33	1.14	1.29
6			0.90	1.19

Table 4 show that the data of fit item in point 24 of SRL questionnaire revealed that all of the questions is valid because it is in range of infit MNSQ of 0.77 until 1.33. Reability value of every question in output Quest can be seen in estimation item and estimation case. A question is reliable when a test produces a consistent result repetitively with the same subjects and conditions. The result of the reability test can be seen in Table 5.

Table 4. MNSQ Infit and MNSQ Outfit Values on SRL Items

Indicator	Item Number	SRL	
		Infit MNSQ	Outfit MNSQ
Rehearsal Strategies	1	1.10	1.19
	2	1.11	1.14
Elaboration Strategies	3	1.09	1.11
	4	0.98	0.93
	5	1.02	0.98
Metacognitive Self-Regulation	6	0.97	1.01
	7	0.94	0.96
	8	0.88	0.82
	9	1.02	1.05
Mastery self-talk	10	1.01	0.99
	11	0.90	0.87
Relevance Enhancement	12	1.10	1.12
	13	1.10	1.13
Performance/relative ability self-talk	14	1.0	1.17
Environmental	15	0.94	0.90
	16	0.98	0.106
Self-Consequating	17	0.97	0.92
Effort Regulation	18	0.94	0.98
	19	0.95	0.93
	20	0.97	0.93
Regulating Time and Study Environment	21	1.00	0.98
	22	1.04	1.01
General Intention to Seek Needed Help	23	0.95	0.92
	24	0.94	0.92

Table 5 show the coefficient summary of case estimates to HOTS Pretest Question and Posttest are 0.77; hence, the SRL questionnaire is 0.72. According to Gliem and Gliem (2003), the three coefficient values of capability summary of case estimates are acceptable. Hence, the coefficient value of capability of summary estimates in HOTS pretest questions and SRL questionnaire are 0.79 and 0.82 belong to acceptable categorization. In the capability questions HOTS posttest is 0.82 belongs to good categorization.

Table 5. Reability Value

Kind of Question	Reability Coefficient	
	Summary of Item Estimates	Summary of Case Estimates
HOTS Pretest Questions	0.79	0.70
HOTS Posttest Questions	0.82	0.70
SRL Questionnaire	0.74	0.72

All of the instruments that have been validated can be directly used in the learning process. The research was conducted in one of the senior high schools in Yogyakarta, the 11th grade of natural sciences; students began with taking pretest HOTS questions and filling out SRL questionnaires. It was done to know the capability of students before doing any actions. Hence, the other process was teaching-learning process using e-module based on the learning cycle 7E and end by final learning with posttest of HOTS question and filling SRL questionnaire. The average of pretest and posttest can be seen in Table 6.

The result of Table 6 revealed that the HOTS and SRL after posttest was higher than before the pretest using an e-module of learning cycle based 7. It can be seen in the mean or the average score. Thus, it can be concluded that students that learn with e-module based on the learning cycle 7E got better achievement than before the use of e-module of learning cycle 7E based.

Table 6. The Average Result of Pretest – Posttest HOTS questions and Students' SRL Questionnaire

Variabel	Treatment	Mean	Lowest Score	Higher Score
HOTS	Pretest	59.07	34	89
	Posttest	79.80	50	100
SRL	Pretest	78.95	63	97
	Posttest	86.07	68	101

The differences between the two variables toward the action can be made by using the Hotelling T^2 Test with the help of MANOVA analysis, so it must meet the need of nine pre-qualifications assumptions of MANOVA.

Table 7. The Result Multivariate Normality Test

Variabel	Treatment	Shapiro-Wilk Sig.
HOTS	Pretest	0.139
	Posttest	0.56
SRL	Pretest	0.843
	Posttest	0.151

The research has met the nine pre-qualifications of MANOVA, (1) There are two tied variables which are HOTS and SRL; (2) There are two free variables teaching-learning before and after using an e-module based on the learning cycle 7E measured with giving pretest and posttest; (3) There is no relation between the samples; (4) The samples were more than 25 that is 70 students; (5) There was neither outlier univariate nor multivariate; (6) Which were normally distributed multivariate. Normality test using Shapiro-Wilk Test of Normality with SPSS. The results of the normality test can be seen in Table 7.

The normality test results in Table 7 show that all sig values > 0.05, then H_0 is accepted. So it can be concluded that all data comes from a normally distributed population; (7)There are linear relations in every tied pair variable to every free variable; (8) Homogeneity can be seen from the value of Box's Test of Equality of Covariance Matrices (Box's M) can be seen in Table 8.

Table 8. The Results Homogeneity Test

Box's M	2,354
F	0.772
df1	3
df2	3.428E6
Sig.	0.509

Table 8 shows that the Box's M value is 2,354 with a significance value of two-tailed sig. 0.509 > 0.05, then H_0 is accepted. So it can be concluded that the covariance variance matrix is homogeneous; (9) No multi-collinearity was shown by looking at the Tolerance and VIF values, as shown in Table 9. Table 9 shows the results of the multicollinearity test.

Table 9. The Result Multicollinearity Test

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
	B	Std. Error	Beta			Tolerance	VIF
(Constant)	-1.318	0.366	-	3.602	0.00		
SRL	0.022	0.004	0.351	5.011	0.00	0.940	1.064
HOTS	0.014	0.002	0.416	5.935	0.00	0.940	1.064

If the tolerance value > 0.10 and VIF < 10, the data is free from multicollinearity symptoms. The results of the multicollinearity test on the research data are the Tolerance value = 0.940 and the VIF value = 1.064. So it can be concluded that the data is free from multicollinearity symptoms at 0.940 > 0.10 and 1.064 < 10. The nine pre-qualifications of MANOVA have been fulfilled than in the other process can be analyzed with the use of MANOVA to prove the research hypotheses.

3.1.1. Multivariate test

Multivariate test was used to know the differences in HOTS and SRL before and after using the e-module based on the learning cycle 7E. The multivariate test can be seen in a multivariate test of Hotelling's test Trace in Table 10.

Table 10. The Result of Multivariate Test

Test	F	Sig.	Result	Partial Eta Squared
Hotelling's Trace	39.846a	0.000	H_0 declined	0.368

Table 10 show the result of the multivariate test. The decision was taken by comparing the multivariate test with the multivariate criterion test. The decision was taken using α = 0.05 if the value of Hotelling's Trace sig. < α then H_0 is declined, and H_a accepted. It can be concluded that both tied variables were different with specific actions. Based on the analyses results of the multivariate test in Table 10, Hotteling's Trace sig. 0.000 < 0.005, so H_0 was declined, and H_a was accepted. Thus, it can be concluded that there were differences in HOTS and SRL before and after the use of e-module based on the learning cycle 7E.

The result of the research is in line with the Istuningsih et al. (2018) research based on the result of pretest and post-test that showed the use of a scientific approach with the use of an e-module of learning cycle 7E based is effectively used in teaching-learning process. In Table 10, Partial Eta Squared revealed how much the influence of media that is developed toward the tied variable. The percentage toward the influence of the e-module in the teaching process toward HOTS can be known by multiplying it with 100% of the score in partial eta squared. The result of partial eta squared is 0.368 x 100% = 36.8%, it means the effectivity contribution percentage of e-module based on the learning cycle 7E toward HOTS and SRL was 36.8%.

3.1.2. Univariate Test

The next MANOVA test is the Univariate Test (Intermediate Test – Subject Effect). The test was conducted to determine the differences in students' HOTS before and after using the e-module on the buffer solution concept. However, the test is also used to determine the differences in students' SRL before and after using the module based on the 7E learning cycle in the concept of a buffer solution as well. The results of the Between-Subject Effect Test can be seen in Table 11.

Table 11. The Result of Test of Between-Subject Effect

Tied Variable	Sig.	Partial Eta Squared
HOTS	0.000	0.252
SRL	0.000	0.205

The test of Between – Subject Effect with decision criterion used if the signification < α = 0.05 thus H_0 is declined and if the sig. is > 0.05 so the H_0 is accepted (Pallant, 2007). Table 11 show the significant score of HOTS is 0.000 with the partial eta squared 0.252, which meant H_0 was declined so there are differences in students' HOTS before and after the use of e-module based on the learning cycle 7E in buffer solution concept.

Salbiah et al. (2015) said that HOTS are involved critical thinking, creativity, logic, reflectivity, skill to solve the problem, and metacognition. Budiarti et al. (2016) found that the using of e-module helps increase the students' critical thinking. The result is in line

with the research of Sauki and Talib (2020) that with the use of Polysa method, 5E and 7E can answer the questions of HOTS and it can increase students' learning achievement.

The research result of Kusumawardani et al. (2019) show that learning process using learning cycle 7E model had proven can increase students' learning achievement than the students taught using 5E learning cycle. The practical contribution percentage of an e-module toward HOTS was 25.2%. The test score of between-subject effect sig. 0.000 < 0.05 thus, H_0 was declined, and can be concluded that there were differences SRL of students before and after the use of e-module based on the learning cycle 7E with the number contribution of 20.5% seen from the score of partial eta square. The finding result is in line with the research of Khoiriah et al. (2019) showed that the application of instrument scoring of the effective HOTS can develop the SRL of students. It was in line with the Brookhart's statement (2010) that said students' who have good habitual action of HOTS and SRL.

4. Conclusion

There is the difference between HOTS and SRL of students simultaneously before and after the use of e-module based on the learning cycle 7E in buffer solution concept. The effectiveness contribution of HOTS and SRL of students simultaneously was 36.8%, for HOTS was 25.2%, and for the SRL was 20.5%.

This research has important implications for chemistry education, which are syllabus and chemistry teachers can use lesson plans as guidelines for implementing learning with the learning cycle 7E model assisted by e-module or other media; Pretest and posttest questions of HOTS can be used to assess students' learning achievement so that they can practice working on questions with a high cognitive level.

Some further recommendations that can be considered for further research are developing and implementing an e-module based on the learning cycle 7E on other chemistry concept. In addition, other research can be done by comparing the use of e-modules based on the 7E learning cycle with similar studies based on the 9E learning cycle.

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