Electronic Module Based Multiple On Buffer Solution

Jerome V. Cleofas[1]
Department if Sociology and Behavioural Sciences, De La Salle University, Manila , Philippines
Ian Christopher N. Rocha[2]
School of Medicine, Centro Escolar University, Manila , Philippines
Rey G. Parcon[3]
Institute of Accounts, Business and Finance, Far Eastern University , Manila , Philippines

Corespondence : Ian Christopher N. Rocha(icnrocha.research@gmail.com)

Abstract

Abstract The purpose of this study is to compare the self-regulated learning (SRL) and cognitive learning outcomes (CLO) of students who use multiple representation-based e-modules to students who use other teaching materials that are not based on multiple representations on buffer solution materials, as well as to determine the percentage of effective contribution. The subjects of this study were students in class XI MIPA at one of Bandung's high schools. Cluster random sampling was used using a quasi-experiment approach and a posttest-only control group design. Questionnaires on self-regulated learning and cognitive learning outcomes were employed as tools. The data analysis approach employed in the field test findings was Hotelling's Trace test, and effective contribution was calculated using the Partial Eta Squared value. The results revealed a significance value of 0.000 0.05, implying that there are differences in SRL and CLO of students who use multiple representation-based e-modules and students who use other teaching materials without multiple representations based on buffer solution materials. The effective contribution of e-module use to SRL is 16.5%, CLO is 11.8%, and SRL and CLO is 20.3%.

Keywords: Buffer solution; Cognitive learning outcomes; E-module; Multiple representations; Self-regulated learning

Introduction

Creactions or natural events that occur and is then scientifically described (Akaygun, 2016; Wu & Shah, 2004) as well as taking matter as an object (Andani & Yulian, 2018; Mujakir & Rusydi, 2019). Although it is directly connected to natural events, chemistry is uninteresting for students to master since learning in schools is focused on memorizing chemical ideas without comprehending, making pupils feel difficult. This is consistent with the characteristics of abstract chemistry, which make chemistry a difficult science for most students to understand (Chandrasegaran, Treagust, & Mocerino, 2007; Ristiyani & Bahriah, 2016), and learners are asked to believe in something without seeing or being observed (Nastiti et al., 2012; Stojanovska, Petruevski, & optrajanov, 2014).

Chemistry may be comprehended using three chemical representations: macroscopic, submicroscopic, and symbolic (Chittleborough & Treagust, 2007; Chiu & Wu, 2009; Gkitzia, Salta, & Tzougraki, 2011), also known as "triplet chemistry" (Talanquer, 2011). The use of representations in chemistry learning can make chemical ideas easier to grasp and more enjoyable (intelligible, believable, and rewarding), motivating students to learn chemistry (Farida, 2009). However, according to the findings of Chittleborough and Treagust (2007) research, pupils have trouble grasping chemical ideas because they are unable to envision them structures and reactions at the particle level and are unable to connect them to other chemical representations.

Students must have representational abilities to minimize misunderstandings about chemical content

(Farida, 2009; Kozma & Russell, 2005; Olimpo et al., 2015; Stieff, 2011) because the interrelationship of three chemical representations can assist construct students' understanding of chemical concepts and phenomena (Treagust et al., 2003). According to the findings of Sunyono et al. (2013), chemical learning does not entail all three levels of representation, but instead focuses on the macroscopic level, with submicroscopic representations being overlooked. This is due to the teacher's limited ability to impart representations at the macroscopic and symbolic levels. These deficiencies cause students' understanding to be dominated by understanding macroscopic and symbolic representations only, resulting in a weak submicroscopic understanding of students and an incomplete mental model (Suja, Yuanita, & Ibrahim, 2017; Syarifuddin & Dwiningsih, 2020). Ignoring one of the consequences of chemical representation in learners who merely memorize material without fully grasping the topic lowers the quality of chemistry learning in schools (Handayanti et al., 2015). According to the findings of Li and Arshad (2014), learning that relies on memorizing concepts or materials is a barrier to effective chemical learning. As a result, many students have misunderstandings (Apriadi et al., 2018)

Because it is a complex material that is widely found in everyday life and the human body (Marsita, Priatmoko, & Kusuma, 2010), the buffer solution material (Devi & Indriyanti, 2018; Nurhujaimah et al., 2016; Nurusshobah et al., 2018) is one of the chemical materials that frequently experiences misconceptions and contains three levels of representation. According to the findings of Mentari et al. (2014), several students had misunderstandings regarding the idea of a buffer solution of 52.45%. Misconceptions can be harmful to a learner's learning achievement, particularly his cognitive learning performance (Salirawati, 2011). Students' poor cognitive learning results are driven by a shortage of teaching resources in schools (Julia et al., 2016). As a result, instructional aids that can depict abstract chemical compounds are required (Amalia et al., 2020)..

The e-module is one of the instructional resources that may be used to visualize chemical materials. Educators in the twenty-first century must give innovation and optimize the usage of technology (Mardhiyana & Nasution, 2018). However, in the field, there are still many schools that are based on computer and network technology, but their use has not increased been increased to the point where students are unable to successfully use technology, resulting in less exciting learning and students being less active (Fadloli et al., 2019; So, Chen, & Wan, 2019). Technology can be used to create interesting teaching materials, assist students in problem-solving skills, and involve macroscopic, submicroscopic, and symbolic representations so that students can learn independently without relying on others including educators because it can be used anywhere and at any time (Baptista et al., 2019; Gabby et al., 2016; M.-C. Li & Tsai, 2013; Triyono, 2015; Wallace, 2003; Zhang et al.

E-modules are one type of learning facility that can help students enhance their self-regulated learning (SRL) (Harefa & Silalahi, 2020; Linda et al., 2021). According to Suyoso and Nurohman (2014), e-modules paired with diverse representations can increase students' cognitive learning outcomes (CLO). However, there hasn't been a lot of availability of e-modules that interact with different representations. To improve SRL and CLO, an e-module that follows the standard format and comprises three levels of comprehensive chemical representation is required in chemistry learning (Asmiyunda et al., 2018; Hamdi et al., 2015). The goal of this study is to compare the SRL and CLO of students who utilize multiple representation-based e-modules to students who use alternative instructional methods.resources that do not employ multiple representations, and to determine the proportion of effective contribution of e-modules in the learning process.

Method

Research Design

This study employed a quasi-experimental approach with a posttest-only control group in two randomly selected classes. The classes utilized are separated into two types: control classes and experiment classes. Control classes are those whose learning is focused only on teaching contents and not on numerous representations. The experiment class employs numerous representation-based e-modules in its learning. Blended learning was used to acquire research data. The study's design is shown in Table 1.

Table 1. Research Design

Group	Treatment	Posttest
Experiment	X1	O1P2
Control	X2	O1P2

Information:

X1 : Learning using multiple representation-based e-modules

X2 : Learning using teaching materials without being based on multiple representations

O1 : SRL Qirstionnaire

P2 : Coginitive learning outcomes test

Sample

This study included 72 students from a Bandung high school's class XI science class. The sampling approach employed was cluster random sampling, which assumed that specific characteristics possessed by each group were not taken into account in the study (Creswell & Creswell, 2018). Prior to using the SRL questionnaire and CLO exam, empirical validation of the SRL questionnaire was performed on 241 students, and CLO test validation was performed on 80 students who had studied the buffer solution content.

Data Collection Techniques and Instruments

The data collection techniques used in this research are test and non-test techniques. The test technique used the CLO test. Non-test techniques were used in the SRL questionnaire. CLO test consist of 22 multiple-choice questions with varying cognitive levels. The SRL questionnaire consists of 27 statements based on SRL factors, such as motivation, independence, self- confidence, and responsibility with responses using the Likert scale.

Validity and Reability Test

This study included both test and non-test data gathering methodologies. The CLO test was utilized in the testing procedure. The SRL questionnaire employed non-testing procedures. The CLO exam consists of 22 multiple-choice questions of different cognitive difficulty. The SRL questionnaire consists of 27 items based on SRL elements such as motivation, independence, self-confidence, and responsibility, with Likert scale responses.

Table 2. Item Estimate and Case Estimate Value Category

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

The consistency of the test measurement findings, or the degree of precision and accuracy given by the instrument, is referred to as reliability. Even if given/tested against various samples, the instrument item will produce the same findings (Bond et al., 2020). The item estimate index and the person separation index (case estimate) can be used to calculate the estimated reliability of questions based on the item response theory. Table 2 shows the value of the item estimate and case estimate according to Smith (2005).

Research Data Analysis

The data was analyzed in multivariate mode using the Multivariate Analysis of Variance (MANOVA) approach with a significance threshold of 0.05. In MANOVA analysis, numerous statistical tests are employed to make conclusions based on hypotheses, including Pillai's Trace, Wilk's Lambda, Hotelling's Trace, and Roy's Largest Root (Khattree & Naik, 2000). The Hotelling's Trace test was used in this study. This test was chosen since there were only two independent groups of variables, the sample size was enough, and the variance-covariance matrix homogeneity requirement was fulfilled (Stevens, 2009).

Following the Hotelling's Trace test, a univariate test, termed the Test of Between-Subject Effect, is performed. The univariate test is used to determine the difference between SRL and CLO after utilizing the e-module. Furthermore, an effective contribution test was performed to measure the impact of using various representation-based e-modules on students' SRL and CLO. The SPSS application is used to calculate effective donations based on partial eta squared values..

Result and Discussion

This study was carried out in one of Bandung's high schools using an emergency curriculum. The learning technique was mixed, meaning that some students learned face-to-face at school while others learned online from home. The learning process was conducted out utilizing the Google Meet platform, Google Classroom for learning information, and Google Forms for SRL data and post-test CLO collection. The taught material is buffer solution material. The learning process begins with communicating the learning goals for each meeting. The researcher then gives an e-module in the form of a link that may be viewed on a smartphone or laptop after giving the learning goals.

The goal of the field implementation experiment is to compare the SRL and CLO of students who use multiple representation-based e-modules to those who utilize alternative teaching materials that are not based on multiple representations. SRL was gathered by filling out questionnaires from students in the control and experiment classes after the buffer solution material learning procedure was completed. The CLO of students was calculated using post-test scores from the experiment and control classes at the conclusion of the learning. The experiment class uses the same question type and question elements as the control class..

SRL Questionnaire Empirical Trial Results

The SRL questionnaire empirical experiment included 241 students. The empirical test of the SRL questionnaire revealed that numerous claims dropped because the MNSQ infit value was not in the range of 0.77 - 1.33 and the MNSQ outfit value was not in the range of 0.50 - 1.50. (2014) (Boone, Staver, & Yale). The item is said to be fit if it satisfies this value (Sumintono & Widhiarso, 2014). According to the data, two statements perished because they surpassed the threshold limit for MNSQ infit values and MNSQ outfits, making the total number of statement items utilized 27 out of 29. The SRL questionnaire's reliability value was calculated using the summary of item estimations and was 0.76. The SRL questionnaire's reliability value was calculated using the summary of case estimates and was 0.72.

CLO Question Empirical Test Results

The CLO empirical trial had 80 students. According to the findings, three question items perished because they surpassed the threshold limit for the MNSQ infit value and the MNSQ outfit, making the total number of question items utilized 22 out of 25. The dependability value of the CLO question earned a reliability rating of 0.93 based on the summary of item estimations. The dependability value of the CLO question acquired a reliability value of 0.87 based on the summary of case estimates.

MANOVA Prerequisite Test Results

The Hotelling's Trace Test using MANOVA analysis may be used to determine the difference between the two variables and the treatment. If the MANOVA test fits the requirements of Manova's nine prequalification assumptions, it can be performed. (1) There are two bound variables, SRL and CLO; (2) There are two free variables, learning that utilized multiple representation-based e-modules and learning that used other instructional materials without multiple representations; (3) There are two groups: the experiment group and the control group; (4) The sample size must be adequate, at least 25 samples. There are 72 students in this study; (5) there is no univariate or multivariate outlier; (6) multivariate normality towards each group; (7) homogeneity of the variance-covariance matrix between groups on the dependent variables; (8) there is a linear relationship between each pair of dependent variables and independent variables; and (9) there is no strong correlation between the dependent variables that can be indicated by the tolerance and the independent variables.

Multivariate Normality Test

The Kolmogorov-Smirnov test was used to perform the multivariate normality test. Table 3 compares the SPSS test results to the multivariate normality test findings .

Table 3. Multivariate Normality Test

Variable	Class	Kolmogrov- Smirnov		
		Statustics	df	Sig.
SRL	Experiment	0.096	36	0.200
	Control	0.100	36	0.200
CLO	Experiment	0.116	36	0.200
	Control	0.122	36	0.192

The normality test findings revealed that all variables, namely SRL or CLO in the experiment and control classes, had sig values greater than 0.05. As a result, the complete data set of the research sample is normally distributed

Homogeneity Test

Table 4 shows Box's Test of Equality of Covariance Matrices, which can be used to determine homogeneity. The following theories were tested:

H_0 = There is a similarity of the variance-covariance matrix of the dependent variables.

H_1 = No similarity of the variance-covariance matrix of the dependent variables.

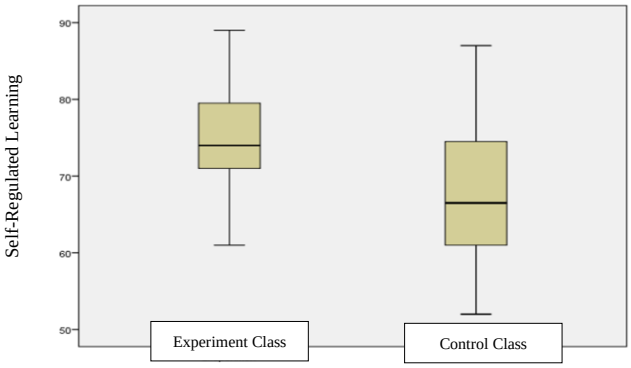
Table 4. Homogeneity Test Results

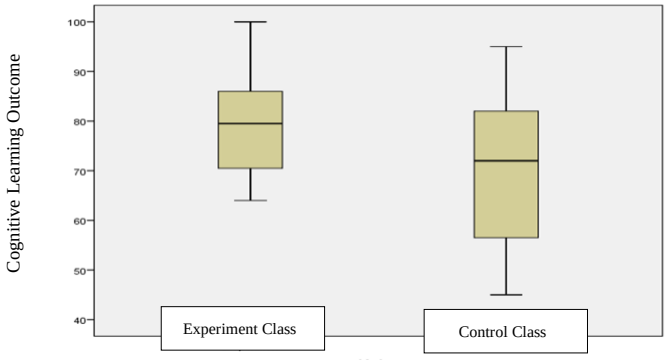
Box's Test of Equality of Covariance Matrices	
Box's M	6,124
F	1,978
df1	3
df2	882000,00
Sig.	0,115

Based on Table 4, a Box's M value of 6.124 was obtained, with a significance value of 0.115. If the Sig value found is greater than 0.5, the hypothesis H0 is accepted, indicating that the variance-covariance matrix of the dependent variable is identical.

Boxplot Test

According to Figure 1, the SRL boxplots test results do not contain univariate outliers since no values emerge from the boxplots in either the experiment or control classes. The CLO boxplots test findings in Figure 2 do not have any univariate outliers. As a result, it can be stated that there are no univariate outliers in the SRL and CLO data..





Multicollinearity Test

Correlations between dependent variables can be shown using tolerance and VIF values. There is no connection (multicollinearity) if the VIF value is more than 10. Table 5 displays the results of the tolerance and VIF value testing

Table 5. Multicollinearity Test Results

Variable	Colinearity Statistics	
	Tolerance	VIF
SRL	0.833	1.201
CLO	0.833	1.201

According to Table 5, the tolerance value of SRL and CLO is greater than 0.01, which is 0.083 greater than 0.01. SRL and CLO had a VIF value of 1,201, of which 1.201 10. Thus, based on the tolerance and VIF values in the dependent variable, it is possible to conclude that there is no strong association (multicollinearity). Based on the SPSS test results for the MANOVA prerequisite assumption test, it is possible to conclude that all MANOVA precondition tests have been satisfied. As a result, the study's data may be continued and analyzed using MANOVA..

Manova Analysis Results and Effective Contribution Analysis

The MANOVA analysis is performed once the prerequisite test has been completed and all prerequisite tests have been satisfied. MANOVA analysis was used to validate the study hypothesis. The presence or lack of significant differences in SRL and CLO between students who use multiple representation-based electronic modules and students who utilize alternative instructional materials without multiple representations was tested using hypothesis testing. There are three hypotheses in the study.

First Hypothesis

H_0 = There were no significant differences in SRL and CLO of learners in the control class and experiment class.
H_1 = There are significant differences in SRL and CLO of learners in control classes and experiment classes.

Second Hypothesis

H_0 = There is no difference in learner SRL in the control class and experiment class.
H_1 = There are differences in learner SRL in the control class and experiment class.

Third Hypothesis

H_0 = There was no difference in the CLO of learners in the control class and the experiment class.
H_1 = There are differences in CLO of learners in the control class and experiment class.

Multivariate Test

Because there were only two groups of self-regulated variables, the sample was sufficient, namely more than 25 samples, and the prerequisite for homogeneity of the variance-covariance matrix was met, the SPSS program was used to test the first hypothesis using the results of the multivariate test of the Hoteling's Trace test. Table 6 shows the results of the multivariate test.

Table 6. Multivariate Test Results

Test	F	Sig.	Result	Partial Eta Squared
Hotelling's Trace	8.800b	0.000	H0 rejected	0.203

The results of multivariate testing using Hotelling's Trace are shown in Table 6. In multivariate testing, significance values = 0.05 are used to make decisions. If the significance value of Hotelling's Trace is less than 0.05, H0 is rejected and H1 is accepted. The significant value of Hotelling's Trace = 0.000 was derived based on the test results and the data mentioned in Table 6. As a result, if the value of Sig. Hotelling's Trace is 0.000 0.05, H0 is rejected and H1 is approved. Based on this, it is possible to conclude that the SRL and CLO of students in the experiment class and the control class differ significantly.

Table 6 includes a Partial Eta Squared value that indicates how much effect the multiple-representation-based model has.-

Based on the bound variables SRL and CLO, the electronic module only compares the results of two distinct treatments (Richardson, 2011). Knowing the percentage of electronic modules' effective contribution to SRL and CLO by multiplying the value of Partial Eta Squared by 100%. When the Value of Partial Eta Squared by 100% is multiplied by 0.203, the result is 20.3%, indicating that the proportion of effective contribution of multiple-representation-based e-module to SRL and CLO is 20.3%.

The follow-up results of the multivariate test on the first hypothesis were tested using the SPSS program. The follow-up test of the MANOVA in question is a univariate test through the Test of Between-Subjects Effect table. The results of the Test of Between-Subjects Effect SRL and CLO are presented in Table 7.

Table 7. Test of Between-Subjects Effect SRL and CLO Results

Variable	F	Sig.	Result	Partial Eta Squared
SRL	13.878	0.000	H_0 rejected	0.165
CLO	9.381	0.003	H_0 rejected	0.118

Based on the findings of the between-subjects effect test on the variables SRL and CLO, the choice is made as follows: if Sig. () 0.05, H 0 is refused; if Sig. () > 0.05, H1 is approved (Pallant, 2020; Paris & Paris, 2001). Table 7 shows that the significance value of the variable SRL = 0.000 and the significance value of CLO = 0.003. Thus, the variable SRL has a significance value of 0.000 0.05 while CLO has a significance value of 0.003 < 0.05, indicating that hypothesis H0 was rejected and hypothesis H1 was accepted. Based on this, SRL and CLO students in experiment classrooms who utilize multiple representation-based e-modules vary from students in control classes that use alternative instructional materials that do not employ multiple representations. The representation may then be observed from the partial value of the squared eta multiplied by 100% to find out the proportion of effective contribution of the utilization of multiple-based e-modules. The SRL partial eta squared value was 0.165 x 100% = 16.5%, and the CLO partial eta squared value was 0.118 x 100% = 11.8%, indicating that using numerous representation-based e-modules contributes 16.5% to SRL and 11.8% to CLO of students.

The average score of the results of filling out the SRL questionnaire and CLO exam at the conclusion of learning demonstrates that the e-module contributes effectively to the difference between SRL and CLO. Table 8 shows the average results obtained by the control and experiment classes versus SRL and CLO

Table 8. Average Results of SRL questionnaire and Posttest CLO Learners

Varible	Treatment	Mean	Lowest Score	Higher Score
SRL	Experiment	74.4	61	89
	Control	67.0	52	87
CLO	Experiment	79.3	64	100
	Control	70.0	45	95

Discussion

Implementation of Multiple Representation-Based E-Modules

The CLO post-test findings revealed that the experimental class's average value was greater than the control class's. The findings of this study support previous studies by Kusumaningsih et al. (2018) and Derman & Ebenezer (2018) showing students who use various representations in their learning process have stronger cognitive capacities than others. Similarly, Anggraini et al. (2022) discovered that learning that employs three levels of representation had a favorable influence on students' cognitive skills, particularly their high-level cognitive abilities. Learners who study using three levels of representation have higher reasoning and writing skills in addition to excelling in cognitive capacities.

According to the SRL questionnaire data, the experimental class's average value was greater than the control class's. The findings of this study support the findings of Gevi and Andromeda (2019) and Mufida et al. (2022) that an e-module equipped with videos, animations, images, and questions allows the e-module's self-instruction characteristics to function properly, namely students taking the initiative to learn independently rather than relying on others, particularly educators. In addition to enabling students self-sufficient in their learning, e-modules with numerous representations can inspire and decrease students' learning time by bridging the student's process in comprehending the notion of buffer solutions.

Efektive Contribution

The usage of various representation-based e-modules aided the learning process and the attainment of learning objectives efficiently. A partial eta squared of 20.3% was calculated based on the findings of the multivariate test in Table 6, indicating that e-modules based on multiple representations simultaneously impact SRL and CLO. When the SRL variable was considered, the e-module contributed 16.5%. From the standpoint of CLO, the e-module made an effective contribution of 11.8%. The designed e-modules have a favorable influence on learners' SRL and CLO. The usage of e-modules makes it simpler for students to identify ideas since it has a thorough explanation of the topic, including KI, KD, and indications of competence accomplishment, as well as practice problems. (Agung et al., 2020; Aisyah et al., 2020)

Conclusion

Based on the research, it can be concluded that: (1) there are differences in SRL and CLO of students who use multiple-representation-based e-modules with students who use other teaching materials without multiple representations, (2) there are differences in SRL of students who use multiple representation-based e-modules with learners who use other teaching materials without multiple representations, (3) there are differences in SRL of students who use multiple representation-based e-modules with learners who use other teaching materials without multiple representations impact on pupils' SRL and CLO.,

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