

Implementation of Electronic Module Based Multiple Representation on Buffer Solution Materials to Improve Students' Self-Regulated Learning and Cognitive Learning Outcomes

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Abstract: This research aims to determine the differences between self-regulated learning (SRL) and cognitive learning outcomes (CLO) of students who use multiple representation-based e-modules with students who use other teaching materials without being based on multiple representations on buffer solution materials and to determine the percentage of effective contribution. The subjects of this study were students of class XI MIPA at one of the high schools in Yogyakarta. The sampling technique carried out is cluster random sampling with a quasi-experiment method by posttest-only control group design. The instruments used are questionnaires on self-regulated learning and cognitive learning outcomes. The data analysis technique used in the field test results used Hotelling's Trace test and the results of effective contribution were obtained from the Partial Eta Squared value. The results showed that the significance value of $0.000 < 0.05$ so that H_0 was rejected, which means that there are differences in SRL and CLO of students between students who use multiple representation-based e-modules and students who use other teaching materials without multiple representations based on buffer solution materials. The percentage of effective contribution of the use of e-modules to SRL by 16.5%, CLO by 11.8%, and SRL and CLO by 20.3%.

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

Introduction

Chemistry is a science that describes the mechanism of reactions or natural phenomena occurred then is explained scientifically (Akaygun, 2016; Wu & Shah, 2004) well as taking the matter as an object (Andani & Yulian, 2018; Mujakir & Rusydi, 2019). Although it is closely related to natural phenomena that occurred, chemistry is boring to learn by students because learning in schools is directed to memorizing chemical concepts without understanding so students feel difficult. This is in line because following the characteristics of abstract chemistry, chemistry becomes a science that is difficult for most students to understand (Chandrasegaran, Treagust, & Mocerino, 2007; Ristiyani & Bahriah, 2016), and learners are asked to believe in something without

seeing and not being observed (Nastiti et al., 2012; Stojanovska, Petruševski, & Šoptrajanov, 2014).

The concept of chemistry can be understood through three chemical representations, namely macroscopic, submicroscopic, and symbolic representations (Chittleborough & Treagust, 2007; Chiu & Wu, 2009; Gkitzia, Salta, & Tzougraki, 2011) or often known as "triplet chemistry" (Talanquer, 2011). The use of representations in chemistry learning can make chemistry concepts easy to understand and fun (intelligible, plausible, and fruitful) so that students can be motivated to learn chemistry (Farida, 2009). However, the results of research from Chittleborough and Treagust (2007) state that students have difficulty understanding chemical concepts because they are unable to visualize

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structures and reactions at the particle level and are unable to relate them to other chemical representations.

The interrelationship of three chemical representations can assist construct students' understanding of chemical concepts and phenomena (Tregust et al., 2003) so students must have representational abilities to minimize misunderstandings about chemical content (Farida, 2009; Kozma & Russell, 2005; Olimpo et al., 2015; Stieff, 2011). Based on the results of research by Sunyono et al. (2013) stated that chemistry learning does not involve all three levels of representation, but only focused on the macroscopic level so that submicroscopic representations are ignored. This happens because the teacher is only able to convey representations at the macroscopic and symbolic levels. These deficiencies cause students' understanding to be dominated by understanding macroscopic and symbolic representations only so that students' submicroscopic understanding of students is weak and results in the mental model of students becoming incomplete (Suja, Yuanita, & Ibrahim, 2017; Syarifuddin & Dwiningsih, 2020). Ignoring one of the results of the chemical representation in learners only memorizing material without fully understanding the concept, reduces the quality of chemistry learning in schools (Handayanti et al., 2015). In line with the results of research from Li and Arshad (2014) which states that learning that focuses on memorizing concepts or materials is a barrier to meaningful chemistry learning. Thus many learners experience misconceptions (Apriadi et al., 2018).

One of the chemical materials that often experiences misconceptions and contains three levels of representation, namely the buffer solution material (Devi & Indriyanti, 2018; Nurhujaimah et al., 2016; Nurussobah et al., 2018), because it is a complex material and is widely found in everyday life and the human body (Marsita, Priatmoko, & Kusuma, 2010). Based on the results of research by Mentari et al. (2014) showed that many students experienced misconceptions about the concept of a buffer solution of 52.45%. Misconceptions can be detrimental to the learning success of the learner, specifically his cognitive learning success (Salirawati, 2011). The low cognitive learning outcomes of students are caused by the lack of teaching materials used in schools (Julia et al., 2016). Therefore, teaching materials are needed that can visualize abstract chemical materials (Amalia et al., 2020).

One of the teaching materials that can be used to visualize chemical materials is the e-module. In the 21st century, educators are required to provide innovation and optimize the use of technology (Mardhiyana & Nasution, 2018). However, the reality in the field, there are still many schools that are already based on computer and network technology but their use has not

been maximized so that students are not able to utilize technology effectively and resulting in less interesting learning and students becoming less active (Fadloli et al., 2019; So, Chen, & Wan, 2019). The use of technology can create interesting teaching materials, facilitate students in problem-solving skills and can involve macroscopic, submicroscopic, and symbolic representations so that students can learn independently without relying on others including educators because they can be used anywhere and anytime (Baptista et al., 2019; Gabby et al., 2016; M.-C. Li & Tsai, 2013; Triyono, 2015; Wallace, 2003; Zhang et al., 2017).

E-module is one of the learning facilities that can improve the self-regulated learning (SRL) of students (Harefa & Silalahi, 2020; Linda et al., 2021). E-modules combined with multiple representations according to Suyoso and Nurohman (2014) can improve the cognitive learning outcomes (CLO) of students. However, the availability of e-modules that connect with multiple representations has not been much. On that basis, the existence of an e-module that complies with the standard format and contains three levels of complete chemical representation is indispensable in chemistry learning (Asmiyunda et al., 2018; Hamdi et al., 2015) to improve SRL and CLO. The purpose of this study is to find out the difference between SRL and CLO of students who use multiple representation-based e-modules with students who use other teaching materials without multiple representation-based and to find out the percentage of effective contribution of the use of e-modules in the learning process.

Method

Research Design

This research used a quasi-experiment method in a posttest-only control group design which was carried out in two randomly selected classes. The classes used are divided into two kinds, namely the control class and the experiment class. Control classes are classes whose learning uses teaching materials without being based on multiple representations. The experiment class is a class whose learning uses multiple representation-based e-modules. Research data was collected by blended learning. The design of the study is presented in Table 1.

Table 1. Research Design

Group	Treatment	Posttest
Experiment	X ₁	O ₁ P ₂
Control	X ₂	O ₁ P ₂

Information:

- X₁ : Learning using multiple representation-based e-modules
- X₂ : Learning using teaching materials without being based on multiple representations

- O₁ : SRL Questionnaire
- P₂ : Cognitive learning outcomes test

Sample

This study involved 72 students of class XI science in one of the schools in Yogyakarta. Sampling used a cluster random sampling technique that assumed that certain features possessed by each group were not taken into account in the study (Creswell & Creswell, 2018). Before the SRL questionnaire and CLO test were used, empirical validation of the SRL questionnaire was carried out on 241 students and CLO test validation on 80 students who had studied the buffer solution material.

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 Reliability Test

The research instruments used, namely the test and questionnaire, were validated first theoretically by expert judgment and validated empirically by testing first to students. The empirical validation test of the results of students' answers was analyzed using Rasch model analysis, namely by analyzing item response theory with the QUEST program (Bond et al., 2020). Rasch models can generate a table of the probability of response to items so that they can find out the suitability of the question item (fit item) and its reliability value.

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

Reliability is the consistency of the measurement results of the test or the degree of accuracy and accuracy indicated by the instrument. The instrument item will show the same results even if given/tested against different samples (Bond et al., 2020). The estimated reliability of the questions according to the item response theory can be known based on the item estimate index and the person separation index (case

estimate). The value of the item estimate and case estimate according to Smith (2005) was presented in Table 2.

Research Data Analysis

Analysis of the data used was using multivariate analysis with the Multivariate Analysis of Variance (MANOVA) technique with a significance level of 0.05. There are several statistical tests in MANOVA analysis used to make decisions from hypotheses, among them Pillai's Trace, Wilk's Lambda, Hotelling's Trace, and Roy's Largest Root (Khattree & Naik, 2000). The test conducted by this research is Hotelling's Trace test. The use of this test was chosen because there were only two independent groups of variables, the sample was sufficient, and the prerequisite homogeneity of the variance-covariance matrix was met (Stevens, 2009).

The step after conducting the Hotelling's Trace test is to conduct a univariate test, namely the Test of Between-Subject Effect. The purpose of the univariate test is to find out the difference between SRL and CLO after using the e-module. Furthermore, an effective contribution test was carried out to determine the effectiveness of the use of multiple representation-based e-module on SRL and CLO of students. Effective donations are obtained through partial eta squared values using the SPSS program.

Result and Discussion

This research was conducted at one of the high schools in Yogyakarta using an emergency curriculum. The learning process was carried out in a blended learning manner, namely some students learn face-to-face at school and some others learn online from home. The learning process was carried out using the google meet platform, google classroom as learning information, and google forms in collecting SRL data and post-test CLO. The material taught is buffer solution material. The learning process begins with conveying the learning objectives that will be delivered at each meeting. After delivering the learning objectives, the researcher provides an e-module in the form of a link that can be opened on a smartphone or laptop.

The purpose of the field implementation trial is to find out the differences between SRL and CLO of students who use multiple representation-based e-module with students who use other teaching materials without being based on multiple representations. SRL was obtained from filling out the questionnaires of students in the control class and experiment class after the learning process of the buffer solution material is fully delivered. The CLO of students was obtained from the results of post-test scores in the experiment class and the control class at the end of the learning. The question

type and the question items used in the experiment class are the same as in the control class.

SRL Questionnaire Empirical Trial Results

The empirical trial of the SRL questionnaire involved 241 learners. The results obtained in the empirical test of the SRL questionnaire were that there were several items of statements that fell 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. (Boone, Staver, & Yale, 2014). If it meets this value then the item is said to be fit (Sumintono & Widhiarso, 2014). Based on the results obtained, there were 2 items of statements that died because they exceeded the threshold limit for MNSQ infit values and MNSQ outfits so the statement items used were 27 items out of 29 items. The reliability value of the SRL questionnaire based on the summary of item estimates obtained a reliability value of 0.76. The reliability value of the SRL questionnaire based on the summary of case estimates obtained a reliability value of 0.72.

CLO Question Empirical Test Results

The CLO empirical trial involved 80 learners. Based on the results obtained, 3 question items died because they exceeded the threshold limit for the MNSQ infit value and the MNSQ outfit so the question items used were 22 items out of 25 items. The reliability value of the CLO question based on the summary of item estimates obtained a reliability value of 0.93. The reliability value of the CLO question based on the summary of case estimates obtained a reliability value of 0.87.

MANOVA Prerequisite Test Results

Knowing the difference between the two variables and the treatment can be done using the Hotelling's Trace Test with the MANOVA analysis. The MANOVA test can be performed if it meets the needs of manova's nine prequalification assumptions. The nine prequalification assumptions are (1) There are two bound variables, namely SRL and CLO; (2) There are two free variables, namely learning that used multiple representation-based e-modules and learning that used other teaching materials without multiple representations; (3) There are different groups, namely the experiment group and the control group; (4) The sample must be sufficient, at least 25 samples. The number of samples in this study was 72 students; (5) There is no univariate or multivariate outlier; (6) Multivariate normality towards each group; (7) There is a 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 VIF values.

Multivariate Normality Test

The multivariate normality test was carried out with the Kolmogorov-Smirnov test. The results of the SPSS test against the multivariate normality test are presented in Table 3.

Table 3. Multivariate Normality Test

Variable	Class	Kolmogorov-Smirnov		
		Statistics	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 results of the normality test showed that all variables, namely SRL or CLO in the experiment class and control class, all had a sig value of > 0.05. Thus, it can be concluded that the entire data of the study sample is normally distributed.

Homogeneity Test

Homogeneity can be known by looking at Box's Test of Equality of Covariance Matrices presented in Table 4. The hypotheses tested are:

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 with a significance value of 0.115 was obtained. Sig value. obtained is 0.115 > 0.5, then the hypothesis H_0 is accepted which means that there is a similarity of the variance-covariance matrix of the dependent variable

Boxplot Test

Based on Figure 1, the results of the SRL boxplots test do not contain univariate outliers because there are no values coming out of the boxplots in the experiment class or in the control class. In Figure 2, the results of the CLO boxplots test do not contain univariate outliers. So, it can be concluded that univariately, data on SRL and CLO there are no univariate outlier.

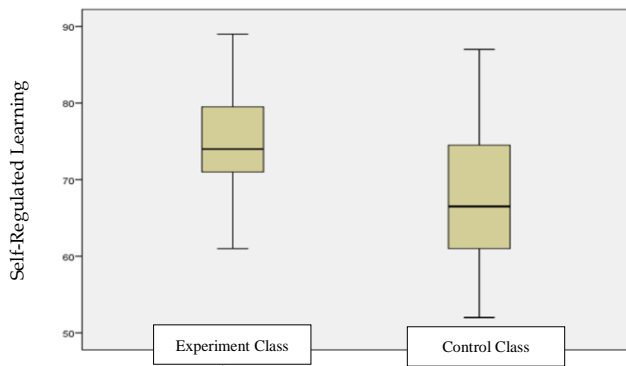


Figure 1. Self-Regulated Learning Boxplot Test Result

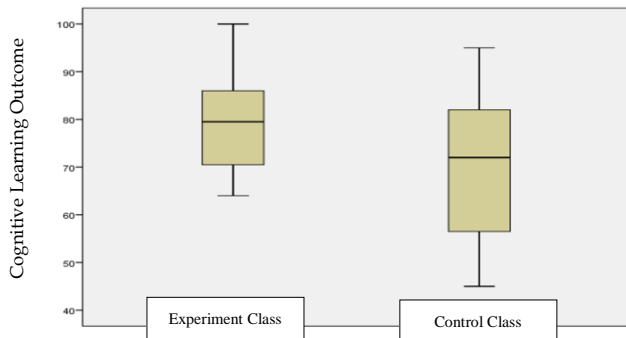


Figure 2. Cognitive Learning Outcome Boxplot Test Result

Multicollinearity Test

Tolerance and VIF values can show correlations between dependent variables. If the tolerance value > 0.01 then there is no strong correlation (multicollinearity). If the VIF value < 10 then there is no strong correlation (multicollinearity). The results of the tolerance and VIF value tests are presented in Table 5.

Table 5. Multicollinearity Test Results

Variable	Colinearity Statistics	
	Tolerance	VIF
SRL	0.833	1.201
CLO	0.833	1.201

Based on Table 5, the tolerance value of SRL and CLO > 0.01, which is 0.083 > 0.01. The VIF value of SRL and CLO was 1,201, of which 1.201 < 10. Thus, it can be concluded that based on the results of the tolerance and VIF values in the dependent variable, there is no strong correlation (multicollinearity). Based on the results obtained through the SPSS test related to the MANOVA prerequisite assumption test, it can be concluded that all MANOVA prerequisite tests have been met. Thus, the data from the study can be continued and can be analyzed using MANOVA.

Manova Analysis Results and Effective Contribution Analysis

After conducting the prerequisite test and the prerequisite test has all been met, then the MANOVA

analysis is then carried out. MANOVA analysis was carried out to prove the research hypothesis. Hypothesis testing was carried out to determine the presence or absence of significant differences in SRL and CLO in students who use multiple representation-based electronic modules with students who use other teaching materials without multiple representations. The study has three hypotheses.

First Hypothesis

H₀ = There were no significant differences in SRL and CLO of learners in the control class and experiment class.

H₁ = There are significant differences in SRL and CLO of learners in control classes and experiment classes.

Second Hypothesis

H₀ = There is no difference in learner SRL in the control class and experiment class.

H₁ = There are differences in learner SRL in the control class and experiment class.

Third Hypothesis

H₀ = There was no difference in the CLO of learners in the control class and the experiment class.

H₁ = There are differences in CLO of learners in the control class and experiment class.

Multivariate Test

In testing the first hypothesis, the SPSS program was used through the results of the multivariate test of the Hotelling's Trace 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 results of the multivariate test are presented in Table 6.

Table 6. Multivariate Test Results

Test	F	Sig.	Results	Partial Eta Squared
Hotelling's Trace	8.800 ^b	0.000	H ₀ rejected	0.203

Table 6 shows the results of multivariate tests using Hotelling's Trace. Decision-making in multivariate tests uses significance values = 0.05. If Hotelling's Trace significance value < 0.05 then H₀ is rejected and H₁ is accepted. Based on the test results and the values listed in Table 6, the significance value of Hotelling's Trace = 0.000 was obtained. Thus, the value of Sig. Hotelling's Trace is 0.000 < 0.05, then H₀ rejected and H₁ accepted. Based on this, it can be concluded that there are significant differences in the SRL and CLO of students in the experiment class and the control class.

In Table 6 there is a Partial Eta Squared value which shows how much influence the multiple-representation-

based electronic module has on the bound variables SRL and CLO which only compare the results of 2 different treatments (Richardson, 2011). Knowing the percentage of the effective contribution of electronic modules to SRL and CLO by multiplying the value of Partial Eta Squared by a figure of 100%. If multiplied by the Value of Partial Eta Squared by 100%, then $0.203 \times 100\% = 20.3\%$, which means that the percentage of effective contribution of multiple-representation-based e-module to SRL and CLO by 20.3%.

The second and third hypotheses were tested using the SPSS program the follow-up results of the multivariate test on the first hypothesis. 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.	Results	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 results of the test of between-subjects effect on the variables SRL and CLO, the decision-making used is if the value of Sig. (α) < 0.05 then H₀ rejected and if the value of Sig. (α) > 0.05 then H₁ accepted (Pallant, 2020; Paris & Paris, 2001). The results obtained in Table 7, that the significance value of the variable SRL = 0.000 and the significance value of CLO = 0.003. Thus, the significance value of the variable SRL is $0.000 < 0.05$ and the significance value of CLO is $0.003 < 0.05$ which means that hypothesis H₀ was rejected and H₁ accepted. Based on this, there are differences in SRL and CLO students in experiment classes who use multiple representation-based e-modules with students in control classes who use other teaching materials without multiple representations. Then to find out the percentage of effective contribution of the use of multiple-based e-modules, the representation can be seen from the partial value of the squared eta which is multiplied by 100%. The SRL partial eta squared value obtained $0.165 \times 100\% = 16.5\%$ and the partial eta squared CLO value obtained $0.118 \times 100\% = 11.8\%$, which means that the use of multiple representation-based e-modules has a contribution of 16.5% to SRL and 11.8% to the CLO of students.

Proving that the e-module contributes effectively to the difference between SRL and CLO can be seen from the average score of the results of filling out the SRL questionnaire and CLO test at the end of learning. The average results obtained by the control classes and

experiment classes against SRL and CLO are presented in Table 8.

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

Variable	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 value of the CLO post-test results showed that the average value of the experimental class was higher compared to the control class. The results of this study are following research that has been carried out by Kusumaningsih et al. (2018) and Derman & Ebenezer (2018) that students whose learning process applies multiple representations have better cognitive abilities than others. Similarly, the results of research by Anggraini et al. (2022) stated that learning that applies three levels of representation has a positive impact on the cognitive abilities of students, especially the high-level cognitive abilities of students. In addition to excelling in cognitive abilities, learners who learn with three levels of representation have better argumentation skills and writing skills. The use of teaching materials equipped with multiple representations can increase the consistency of students in understanding chemical materials and can assist students improve their cognitive abilities because understanding the natural sciences requires a lot of representation and factual insights (Justi & Gilbert, 2002; Rau, 2015).

The SRL questionnaire results showed that the average value of the experimental class was higher than that of the control class. The results of this research are following the research that has been carried out by Gevi & Andromeda (2019) and Mufida et al. (2022) that the e-module equipped with videos, animations, images, and questions provided makes the characteristics of the e-module as self-instruction function properly, namely students take the initiative to learn independently not depending on others, especially educators. In addition to making students independent of learning, e-modules equipped with multiple representations can motivate and shorten the learning time of students because representation can bridge the student's process in understanding the concept of buffer solutions (Dewi et al., 2021; Hurrahman et al., 2022; Wiyarsi, Sutrisno, & Rohaeti, 2018).

Effective Contribution

The use of multiple representation-based e-modules contributed effectively to the learning process and the achievement of learning objectives. Based on Table 6 related to the results of the multivariate test, a *partial eta squared* of 20.3% was obtained, which means that e-modules based on multiple representations simultaneously influence SRL and CLO. When viewed from the SRL variable, the e-module contributed 16.5%. When viewed from CLO, the e-module contributed an effective contribution of 11.8%. The e-modules developed have a positive impact on the SRL and CLO of learners. Through the use of e-modules, it makes it easier for students to find concepts because in it has been presented a complete description of the material following KI, KD, and indicators of competency achievement, and practice questions equipped with completion answers that can assist students find concepts independently so that the results of SRL and CLO funds for students increase (Agung et al., 2020; Aisyah et al., 2020).

Conclusion

Based on the research that has been carried out, it can be concluded that: (1) simultaneously there are differences in SRL and CLO of students who use multiple-representation-based e-module with students who use other teaching materials without multiple representations, (2) there are differences in SRL of students who use e-modules multiple representation-based with learners who use other teaching materials without multiple representations, (3) there are differences in the CLO of learners who use multiple-representation-based e-modules with students who use other teaching materials without multiple representations, (4) the effective contribution of multiple-based e-modules representation on the buffer solution material to SRL and The CLO of students is 20.3%, which means that the use of multiple-representation-based e-modules on buffer solution materials has a positive effect on the SRL and CLO of students.

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Author Contributions

Conceptualization, I.K.S. and I.S.Y.L.; methodology, I.K.S. and I.S.Y.L.; validation, I.S.Y.L.; investigation, I.K.S.; resources, I.K.S.; data curation, I.K.S.; writing-original draft preparation, I.K.S.; writing-review and editing, I.K.S., and I.S.Y.L. All

authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest

The authors declare no conflict of interest.

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