SEM PLS

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Submission date: 01-Nov-2022 12:01AM (UTC+0700)
Submission ID: 1940574878
File name: 01_Article_SEM_PLS_Final.docx (631K)
Word count: 3765
Character count: 22712

Jurnal Elemen, 9(1), 1-10, January 2023
https://doi.org/10.29408/jel.v9i1.XXXX

e- ISSN: 2442 - 4226

Causality of mathematical anxiety, self-concept, self-regulated learning, students academic achievement: SEM_PLS Analysis

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Abstract

This study aimed to obtain significant indicators reflecting the latent variables of mathematical anxiety, self-concept, and self-regulated learning, then to obtain a predictive model of causal influence among variables on students academic achievement. The research used quantitative method by compiling non-test instrument. Evaluating of the validity, reliability, and verification of variable indicators, as well as the formation of a causal model using structural equation model of the partial least squares (SEM-PLS). SEM-PLS analysis resulted all significant indicators that met the criteria in a measurement model, namely convergent validity, discriminant validity, and construct reliability. The causal influence generated in the structural model showed that the pairs of variables that influence each other were mathematical anxiety effected on self-regulated learning, mathematical anxiety effected on self-concept, and self-concept effected on self-regulated learning. The mathematical anxiety variable has a negative effect on self-regulated learning by -0.230. A student who had low mathematical anxiety then his or her self-regulated learning tends to be high. Mathematical anxiety and self-concept also had a negative influence each other. The lower a person's self-concept, the higher of mathematical anxiety will be. The self-concept and self-regulated learning variables had a positive effect of 0.498. A student with high self-concept tends to have high self-regulated learning.

Keywords: academic achievement, latent variables. mathematical self-concept, mathematical anxiety, self-regulated learning, SEM-PLS

Received: Date Month Year | Revised: Date Month Year
Accepted: Date Month Year | Published: Date Month Year

Introduction

Mathematics is one of the compulsory subjects in the higher education curriculum structure in Indonesia for every Diploma and Bachelor program, or in certain study programs it can be replaced with logic courses (Menkumham-RI, 2005). Mathematics is an integrated subject in the curriculum (Kunwar et al., 2020) for various fields of science in various countries (Ertem-Akbas & Cancan, 2020). Mathematics is important in various spheres of life (NCTM, 2000), namely mathematics for life, mathematics as a part of cultural heritage, mathematics for the workplace, and mathematics for the scientific and technical community.

Experience in the field, mathematics students tend to like counting, familiar with formulas or symbols, some even like to tinker with formulas. In addition, they are known as individuals who tend to show serious, diligent, thorough, and high concentration power. Learning and special characteristics that exist in mathematics topics can encourage students to develop their potential related to the components of mathematical skills. Mathematical proficiency or mathematical proficiency is written by NCTM (2000). Mathematical skills can lead to the achievement of success in learning mathematics (Kilpatrick et al., 2001). Student's successfull in academics can be demonstrated by academic achievement.

Student's academic achievement can be influenced by various aspects involved in learning. Cognitive, affective, and psychomotor aspects are three aspects that are always involved in education. The performance of cognitive, motivational, affective and decision-making aspects can be influenced by mathematical self-beliefs (OECD, 2013). In 2012, the Program for International Student Assessment (PISA) investigated the relationship between the components of mathematical self-beliefs, namely self-efficacy, self-concept, anxiety, and mathematical activity in and outside of school. The results of his investigations confirmed the evidence that had previously existed that the components of mathematical self-beliefs were related to one another even though conceptually, each of these factors had differences. In addition, it revealed that the mathematical anxiety factor had a negative relationship with the self-concept or mathematical self-efficacy factor. Mathematical anxiety factor has a negative relationship with math-scores.

Another study on the relationship between mathematical achievement and self-regulated learning factors revealed that one of the elements in self-regulated learning, namely self-evaluation, can increase academic achievement, although the increase is small (Kesici et al., 2011; Labuhn et al., 2010) showed that self-regulated learning was negatively correlated with the level of anxiety about statistics. The results of the study by Sadi & Uyar (2013) indicate that self-regulated learning has an influence on increasing academic achievement.

The results of the study revealed interrelated factors, namely math-anxiety, self-concept, self-regulated learning, and academic achievement. In statistics, the four factors are latent variables, namely variables that cannot be measured directly. Latent variables need indicators to be able to measure them. This study aims to obtain valid and reliable indicators measuring mathematics-anxiety, self-concept, and mathematical self-regulated learning variables, as well as to obtain a predictive model of causal influence between variables on student academic achievement.

Methods

This research used quantitative methods and survey as data collection technique. The research respondents were students of the mathematics and mathematics education study programs in the even semester of the 2019/2020 academic year.

Mathematical anxiety was defined as negative thoughts and feelings when interacting with mathematics. Mathematical self-concept was belief in one's ability to interact with mathematics. Mathematical self-regulated learning was the process of directing aspects of her or his self, namely motivation, cognition, and behavior in learning activities to achieve maximum learning goals. Academic achievement was the cumulative achievement index value of learning outcomes in higher education.

The causal relationship between variables was analyzed using the structural equation modeling-partial least square (SEM-PLS) which was referred to (Ghozali & Kusumadewi, 2016; Joseph F. Hair et al., 2014; Mustofa & Wijaya, 2016). The instruments of variables was measured with an interval scale on range of 1 to 5 which stated strongly disagree to strongly agree. The name of variables and indicators as well their notations were displayed on Table 1.

Table 1. Name of variables, indicators, and notations

No	Name of variables	Indicators	Notations	Number of Item
1	Anxiety (Exogenous)	1. Have negative feelings towards mathematics related to affective aspects	ANX1	5
		2. Have negative thoughts about mathematics related to cognitive aspects	ANX2	5
2	Self-Concept (Exogenous)	1. Believing that you can understand the problem	SC1	6
		2. Believing that you can solve the problem	SC2	2
		3. Believing that you can get achievements	SC3	2
3	Self-Regulated (Endogenous)	1. Setting goals, making plans, organizing	SRL1	4
		2. Conditioning the physical and the environment	SRL2	2
		3. Looking for material related information	SRL3	4
		4. Seek help and review	SRL4	2
		5. Prepare rewards and evaluate yourself	SRL5	2
4	Academic Achievement (Endogenous)	Grade-Point Average	ACH	1

The research hypothesis was displayed on Figure 1. Processing data used SEM-PLS method by SMART-PLS software.

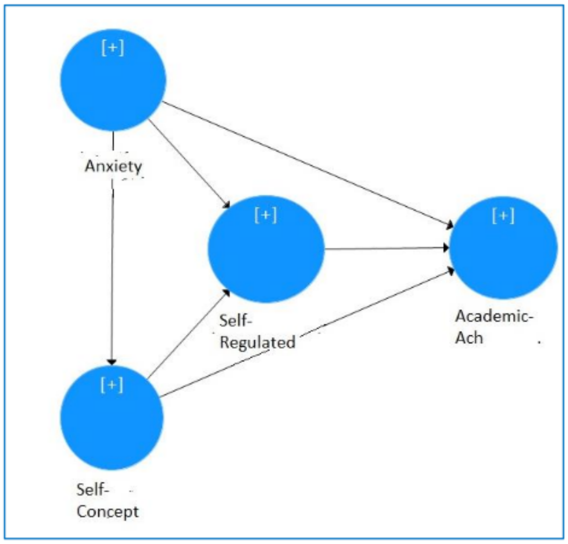

Figure 1. Research hypothesis

Results

Respondents Description

Table 2. Respondents characteristics description

No.	Characteristics		Number of Respondent	Percentage (%)
1	Study Program	Pure Mathematics	127	84.6
		Mathematics Education	33	25.4
2	Grade-Point Average (GPA)	GPA < 2.50	12	8.0
		2.50 ≤ GPA < 3.00	50	27.0
		3.00 ≤ GPA < 3.51	63	42.0
		GPA ≥ 3.51	35	23.0

SEM-PLS: Path Diagram Model

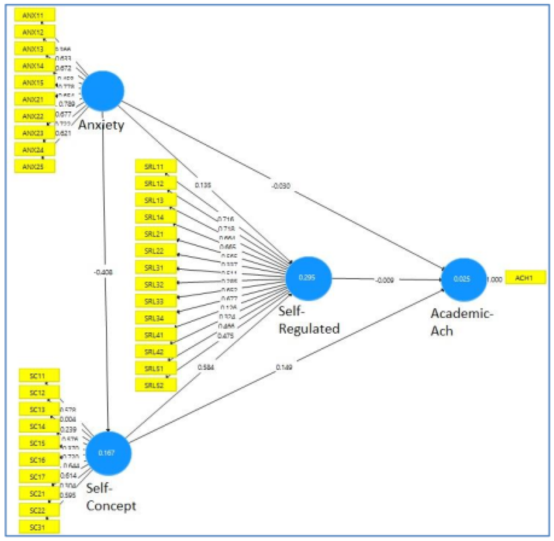

Figure 2. Initial model of SEM-PLS design

SEM-PLS: Measurement Model

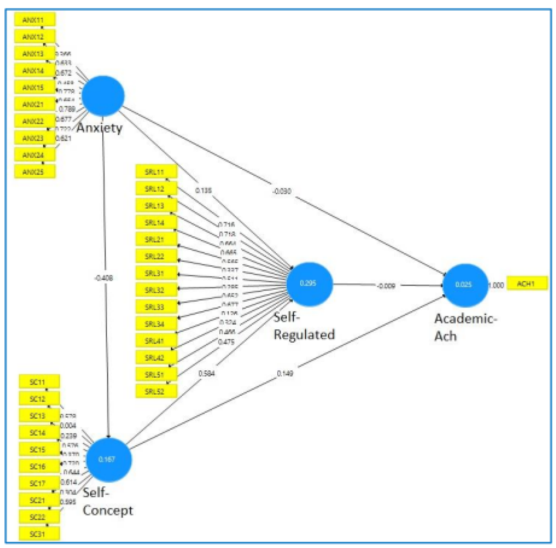

Figure 3. First step of measurement model verification

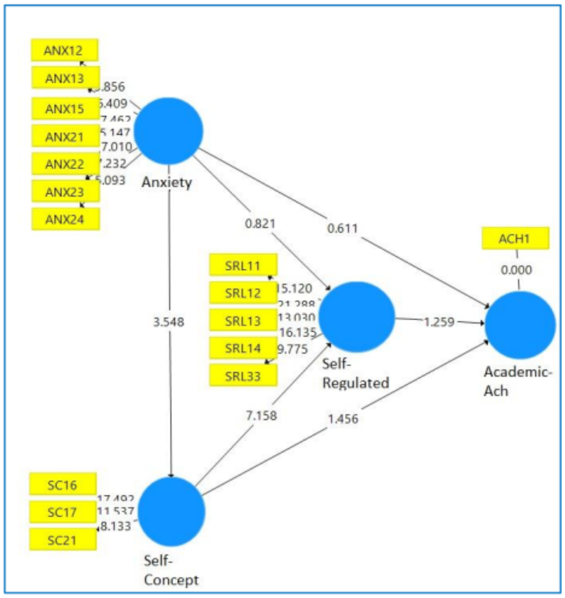

Figure 4. Final step of measurement model verification

Table 3. AVE scores

Variables	AVE
Anxiety	0.503
Self-Regulated	0.554
Self-Concept	0.547
Academic Ach	1.000

Table 4. Outer loading and cross loading values

Indicators	Anxiety (ANX)	Self-Concept (SC)	Self-Regulated (SRL)	Academic Achievement (ACH)
ANX12	**0.641**	-0.131	-0.146	-0.063
ANX13	**0.707**	-0.112	-0.147	0.020
ANX15	**0.777**	-0.121	-0.053	-0.071
ANX21	**0.655**	-0.147	-0.078	0.045
ANX22	**0.760**	-0.244	-0.098	-0.077
ANX23	**0.726**	-0.323	-0.277	-0.117
ANX24	**0.686**	-0.136	-0.063	-0.048
SC16	-0.162	**0.811**	0.470	0.086
SC17	-0.276	**0.728**	0.296	0.012
SC21	-0.217	**0.674**	0.342	0.145
SRL11	-0.240	0.487	**0.757**	0.008
SRL12	-0.175	0.367	**0.799**	-0.048
SRL13	-0.077	0.285	**0.744**	-0.115
SRL14	-0.177	0.398	**0.747**	0.020
SRL33	-0.055	0.276	**0.670**	-0.017
ACH1	-0.085	0.112	-0.032	**1.000**

Table 5. Internal consistency

Variable	Composite Reliability	Cronbach's Alpha
Anxiety	0.876	0.847
Self-Regulated	0.861	0.803
Self-Concept	0.783	0.584
Academic Ach	1.000	1.000

Table 6. Measuring indicators of latent variables

Variables	Indicators	
Anxiety	ANX12	Shy in presenting and sharing answers to mathematical problems
	ANX13	Fear of being laughed at when giving the wrong answer
	ANX15	Thinking that you will fail in completing college
	ANX21	Worried about not being able to quickly solve the mathematical problems
	ANX22	Doubt about the results of the answers to mathematical problems
	ANX23	Thinking about changing majors/study programs
	ANX24	Worried about making mistakes in solving mathematical problems
Self-Concept	SC16	Enjoying the lecture
	SC17	Liked the materials in each course
	SC21	Easy to think in determining the process of working on mathematical problems
Self-Regulated	SRL11	Knowing the purpose of studying in the mathematics study program
	SRL12	Developing a plan that must be done in learning
	SRL13	Immediately re-read the notes of the lessons learned in class
	SRL14	Enjoy working on questions related to the subjects studied
	SRL33	Looking for more than one reading source to support coursework
	SRL34	Regularly check the lecture material notes whether those were complete or not

SEM-PLS: Structural Model

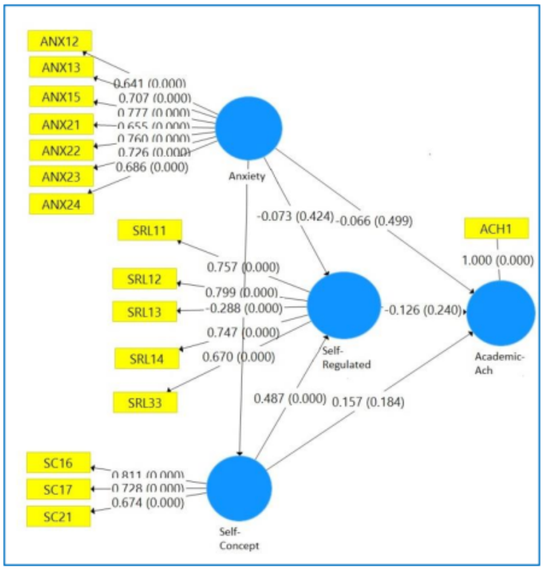

Figure 5. Structural model and test result

Table 7. Indirect effect test

Causal Effects	**Path Coefficients**	**P_Values**
Anxiety → Self-Concept → Self-Regulated	-0.143	**0.004**
Anxiety → Self-Regulated → Academic Ach	0.009	0.563
Self-Concept → Self-Regulated → Academic Ach	-0.050	0.343
Anxiety → Self-Concept → Self-Regulated → Academic Ach	0.014	0.412
Anxiety → Self-Concept → Academic Ach	-0.042	0.283

Table 8. Overall effect test

Effect between Variables	**Path Coefficients**	**P_Values**
Anxiety → Self-Regulated	-0.230	**0.006**
Anxiety → Self-Concept	-0.287	**0.000**
Anxiety → Academic Ach	-0.085	0.421
Self-Regulated → Academic Ach	-0.100	0.314
Self-Concept → Self-Regulated	0.498	**0.000**
Self-Concept → Academic Ach	0.096	0.295

Discussion

A brief description of the respondents based on their study program and academic achievement was shown in Table 2. More than half of the respondents (65%) have a GPA in the range of more than 3-score of 4-scale. This showed that students had a high learning achievements and were included in the very satisfied predicate group. Thus, it could be stated that they had a very good learning outcomes.

SEM-PLS: Path Diagram Model

SEM-PLS is designed to analyze variables that cannot be measured directly namely constructs or latent variables (Hair et al., 2010, 2014). Based on the same reference, SEM-PLS does not require assumptions about data distribution, because SEM-PLS is robust to the assumption of normality. SEM-PLS algorithm is used for metric data but it could be used very well for ordinal and binary scale data. These advantages of SEM-PLS were written by (Joseph F. Hair et al., 2014).

The first stage is to depict a path diagram which describe the relationship among latent variables. It displayed the research hypotheses tested. The variables were mathematical anxiety, self-concept, self-regulated learning, and academic achievement. The diagram was showed on Figure 2 as the initial SEM-PLS model which consists of the measurement and the structural model.

SEM-PLS: Measurement Model

The path diagram on Figure 2 showed the initial measurement model of SEM-PLS and it structural model. The measurement model was shown by a diagram of the relationship among each indicator and each latent variable. The measurement model was verified step by step to test the validity and reliability of the indicators for each latent variable.

The verification process was considered based on the value of loading factors that were less than 0.7 and then had to be removed. The results of the first step of verification were shown in Figure 3. Verification process was repeated until the loading factors values that meet the criteria. Figure 4 was the final result of measurement model that the minimum loading factors values were 0.6. The next process were to check the validity and reliability of the construct.

The construct validity consists of convergent and discriminant validity. The convergent validity was indicated by the value of Average Variance Extracted (AVE) in Table 3. The values of variable AVE were more than 0.5 and these mean that the construct validity was met. The AVE values showed that the variance of each latent variable can be reflected more than 50 percen by variance of its latent variable indicators.

Mathematical anxiety was reflected by seven indicators on Figure 4. Self-concept was reflected by three indicators. Self-regulated was reflected by five indicators. These indicators were explained next on Table 6 and can be used for measuring math-anxiety, self-concept, and self-regulated as valid indicators for next studies.

Discriminant validity was indicated by the value of the outer loading and cross loading of each variable indicator against another variables. Table 4 shows its values. ANX12 has about 0.6 outer loading value on anxiety variable and about -0.1 cross loading value for each self-concept and self-regulated. All of outer loading values were higher than the cross loading values in each indicator variable therefore the discriminant validity was met for measurement model on Figure 4.

The reliability of the measurement model is assessed from internal consistency and indicator reliability. Internal consistency can be seen from the Composite Reliability and

Cronbach's Alpha values with the written criteria (Hair et al., 2010; Joseph F. Hair et al., 2014). The reliability of the indicator is assessed based on the outer loading.

Table 5 displays the Composite Reliability values. All values are more than 0.708 so that the internal consistency criteria have been met. Cronbach's Alpha value for the self-concept variable is around 0.6 but this variable can be maintained for further analysis. The indicators of measurement model in Figure 4 have met the construct validity and reliability.

The indicator reliability criteria are determined from the outer loading value of each indicator whose value must be more than 0.708. An indicator with an outer loading value between 0.40 and 0.70 can still be accepted as a reliable indicator, if the indicator can increase the AVE value. Table 4 shows the values of the outer loading indicators that meet the indicator reliability criteria. Thus, the indicators of the measurement model in Figure 4 have met the validity and reliability of the construct. These indicators presented in Table 6 were used to measure math-anxiety, self-concept, and self-regulated learning.

Mathematical anxiety contained seven indicators that represent affective and cognitive aspects of anxiety. The self-concept contained three indicators consisting of indicators of understanding problems, solving problems, and getting achievements. Self-regulated learning contained six indicators which were four indicators for learning strategies, seeking information, and repeating material.

SEM-PLS: Structural Model

The SEM-PLS structural model is also known as the inner model. The structural model is obtained from the verified measurement model as pictured in Figure 4 consists of two sub-structures that contain direct and indirect relationships to the academic achievement variable. The first sub-structure with endogenous variables self-regulated learning was influenced by mathematical anxiety and mathematical self-concept. The second sub-structure with endogenous variable academic achievement was influenced by mathematical anxiety, mathematical self-concept, and self-regulated learning. The direct and indirect relationships between variables in the sub-structure were tested for significance to obtain a statistically significant structural model. The test results of the structural model are shown in Figure 5.

Mathematical anxiety has a directly and statistically significant effect on self-concept, and the latter variable has a directly influence on self-regulated learning. There were no significant variables that have a direct or indirect effect on academic-achievement. The results of testing an indirect effect between variables were shown in Table 7.

Mathematical anxiety has an indirect effect on self-regulated learning through the self-concept variable. The P_Value in Table 5 was 0.004. All variables have no significant direct or indirect effect on academic achievement. The results of testing the indirect effect between variables are shown in Table 7.

Table 7 shows a pair of variables that influence each other, namely mathematical anxiety on self-regulated learning, mathematical anxiety on self-concept, and self-concept on self-regulated learning. Mathematical anxiety had a negative effect on self-regulated learning as well as on self-concept. This means someone who has a low mathematical-anxiety he/she has a high self-regulated learning. The higher a students' self-concept, the lower their mathematical anxiety. On the other side, self-concept had a significant positive effect on self-regulated learning about number 0.498. The higher a person's self-concept, the higher the self-regulated learning.

Mathematical anxiety has a negative influence on self-concept, meaning that someone who has not been able to control their feelings and thoughts when interacting with mathematics tends to have a high level of mathematical anxiety. In other words, mathematical anxiety can be reduced by increasing the level of self-concept. This result was in accordance with (Gabriel et al., 2020).

Mathematical self-concept is a belief in one's ability to interact with mathematics. Paying attention to significant indicators of self-concept in Table 5 is one of the ways tp increase the level of it. Those indicators were enjoying lectures, liking lecture materials, and thinking easily in determining mathematical problem solving. Learning process should be create as the comfortable condition for students.

Learning material needs to be packaged as well as possible to attract the students, both in terms of substance and appearance so that students can like the content of the message conveyed on each lecture topic. Giving mathematical problems as a trigger for the thought process to work on and solve problems needs to be introduced in various ways in achieving solutions so that students can choose the way that suits their thinking process.

The self-concept variable acts as a good intervening (mediating) variable between mathematical anxiety and self-regulated learning. Mathematical anxiety has a negative impact on self-regulated learning, but this negative impact can be minimized by having a good self-concept. There is a mediating variable for the relationship between mathematical anxiety and self-regulated learning, in line with the results of research (Jain & Dowson, 2009), but with a different variable, namely self-efficacy. The research states that self-efficacy is an important mediating variable in the relationship between mathematical anxiety and self-regulated learning.

Self-regulated learning which can be measured by indicators of goal setting and organizing, seeking information and repeating material. This indicator is part of the same indicator produced by (Jain & Dowson, 2009) who wrote that rehearsal, elaborate, and organize are significant variables closely related to self-regulated learning. The items that represent these indicators can be used to provide recommendations in terms of increasing self-regulated learning to achieve maximum learning goals. Students are given direction and motivation to make learning goals, develop learning plans and techniques, have notebooks, look for additional material as learning support, and repeating the study material.

Mathematical anxiety and self-regulated learning are negatively correlated, in line with those produced by (Gabriel et al., 2020; Jain & Dowson, 2009). The higher level of mathematical anxiety is associated with lower self-regulated learning. Mathematical anxiety is also correlated with self-concept, self-efficacy, motivational strategies which are components of self-regulated learning. Controlling to reduce mathematical anxiety can increase self-regulated learning and provide enthusiasm for learning. The same result was also expressed by (Gabriel et al., 2020).

This study has not been found to reveal the significance of the relationship and causal effect among variables on academic achievement. In contrast to what has been written by (Kesici et al., 2011; Labuhn et al., 2010; Sadi & Uyar, 2013) which revealed that self-regulated learning and the strategies contained in it have a positive effect even though the effect is small on achievement as measured by calculation ability, statistical ability, and academic achievement.

GPA values are still general as a measure of student academic achievement. Therefore, it is necessary to determine more precisely the instrument of academic achievement which is closely related to mathematical anxiety, self-concept, and self-regulated learning. Measurement of academic achievement can be replaced with other more specific variables, such as mathematical understanding, mathematical reasoning, or other mathematical abilities.

Conclusion

The significant indicators of the SEM-PLS model result can be used to measure Mathematical anxiety, self-concept, and self-regulated learning in next studies. GPA as an academic achievement indicator could not be predicted by the causal effect of mathematical anxiety, self-concept, and self-regulated learning.

It is necessary to explore the appropriate variable for measuring student academic achievement. One of the variables is mathematical ability such as mathematical reasoning. The next study can be tried to explore and build the causality model among mathematical abilities, mathematical anxiety, self-concept, self-regulated learning, and academic achievement.

Student academic achievement needs to be explored deeply through various variables including internal and external factors. The example variables are socio-economic factors, interests and motivations, or other psychological factors on learning process.

Conflicts of Interest (13-point, bold)

The authors declare no conflict of interest regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancies, have been completed by the authors.

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