E-ISSN 2654-9948
ALGORITMA Journal of Mathematics Education (AJME)
http://journal.uinjkt.ac.id/index.php/algoritma
Vol. 3 No. 2 – 2021, hal. 116-130

STUDENTS' ANXIETY AND PROBLEM SOLVING ABILITY IN MATHEMATICS LEARNING BASED ON COGNITIVE LOAD THEORY USING AUTOGRAPH SOFTWARE

Kadir Kadir[1]*, Eva Musyrifah[2], Fatimah Fatmawati[3]

[1, 2] **UIN Syarif Hidayatullah Jakarta, Jl. Ir. H. Juanda No.95, Banten, Indonesia**
[3] **SMA Islam Panglima Besar Soedirman Kota Bekasi, Indonesia**
*Email: kadir@uinjkt.ac.id

Abstract

The purpose of the study was to analyze mathematical anxiety, mathematical problem solving ability (MPSA) and student responses in Autograph software based on cognitive load theory. The research was conducted in one of the Madrasah Tsanawiyah in South Tangerang in the 2017/2018 academic year. The method is Classroom Action Research (CAR) in two cycles. Data was collected using observation sheets, questionnaires, daily journals, and tests. The results of the study revealed that Autograph software based on cognitive load theory can reduce mathematical anxiety includes indicators: cognitive, emotional, and physiological. The research findings also revealed that there was an increase in the MPSA including indicators: understanding the problem, divising a plan, carrying out the plan, and looking back. In addition, the positive response of students to Autograph software also increased from cycle I to cycle II. The conclusion of this research is that learning assisted by Autograph software based on cognitive load theory can reduce mathematical anxiety, where students with low mathematical anxiety tend to have higher MPSA and student responses to learning are more positive.

Keywords: mathematical anxiety, problem solving ability, Autograph, cognitive load theory, student response

Abstrak

Tujuan penelitian menganalisis kecemasan matematis, kemampuan pemecahan masalah matematika (KPMM) dan respon siswa dalam pembelajaran menggunakan software Autograph berdasarkan teori beban kognitif. Penelitian dilakukan di salah satu Madrasah Tsanawiyah di Tangerang Selatan tahun ajaran 2017/2018. Metode adalah Tindakan Kelas (PTK) dalam dua siklus. Data dikumpukan dengan lembar observasi, angket, jurnal harian, dan tes. Hasil penelitian mengungkapkan bahwa pembelajaran menggunakan software Autograph berdasarkan teori beban kognitif dapat menurunkan kecemasan matematis yang meliputi indikator: kognitif, emosi, fisiologis. Temuan penelitian juga mengungkapkan bahwa terdapat peningkatan KPMM meliputi indikator: memahami masalah, menyusun rencana, melaksanakan perhitungan, dan memeriksa kembali. Selain itu, respon positif siswa terhadap pembelajaran berbantuan software Autograph juga mengalami peningkatan dari siklus I ke siklus II. Simpulan penelitian ini adalah pembelajaran berbantuan software Autograph berdasarkan teori beban kognitif dapat menurunkan kecemasan matematis, dimana siswa dengan kecemasan matematis rendah cenderung memiliki KPMM lebih tinggi serta respon siswa terhadap pembelajaran lebih positif.

Kata kunci: kecemasan matematis, kemampuan pemecahan masalah, Autograph, teori beban kognitif, respon siswa

How to Cite: Kadir, K., Musyrifah, E., & Fatmawati, F. (2021). Students' Anxiety and Problem Solving Ability in Mathematics Learning Based on Cognitive Load Theory Using Autograph Software. *ALGORITMA Journal of Mathematics Education, 3* (2), 116-130.

Permalink/DOI: http://dx.doi.org/10.15408/ajme.v3i2.24777

Naskah Diterima: Nov 2021; Naskah Disetujui: Des 2021; Naskah Dipublikasikan: Des 2021

INTRODUCTION

Mathematics is a universal and strategic science to support the development of modern technology. Mastering and creating future technologies requires strong mathematical skills from an early age. However, the strategic position of mathematics in life is proportional to students' negative responses to mathematics. Society in general and students in particular consider mathematics to be a difficult subject to learn. Cockcroft stated that students grow up not liking math at all, they find math difficult, scary, don't like doing assignments and can't do them (Krismanto, 2003).

The view of the difficulty of learning mathematics creates feelings of excessive fear causing students' anxiety about mathematics itself. Ashcraft (2022) states mathematical anxiety is a feeling of tension, anxiety or fear that interferes with mathematical performance. Wicaksono and Saufi (2013), said that mathematical anxiety related to feelings and attitudes towards mathematics will affect understanding of mathematics itself. Increased anxiety will worsen students' understanding of mathematics. Furthermore, that students' negative assumptions about mathematics or students' opinions that mathematics is difficult can cause mathematical anxiety

Mathematical anxiety is a feeling of fear that hinders solving mathematical problems both in real life and in academics (Edrogan et al, 2017). Freedman (2017) put forward the definition of mathematical anxiety is an emotional reaction to mathematics that is based on unpleasant experiences in the past and has a negative impact on subsequent learning. Blazer (2011), stated mathematical anxiety can be identified by physical symptoms, such as increased heart rate, sweaty hands, and dizziness. While the psychological symptoms include difficulty in concentrating, retention to attend mathematics session, and loss of interests in learning mathematics. Dzulfikar (2017) argues that a reasonable level of anxiety can have a positive effect as motivation, but excessive anxiety can have a negative effect and disrupt a person's physical and psychological condition. Thus mathematical anxiety is an emotional reaction characterized by fears and worries that arise when facing or interacting with mathematics.

Solving mathematical problems that are not routine and require a level of understanding that is not simple can cause conflicts within students. Research by Lyons and Beilock (2012) shows that mathematical problems can cause the brain to become sick. According to Lin & Lin (2013) that one of the factors that contribute to mathematical anxiety is a math task that is too difficult. Complex tasks will cause students' cognitive load more than simple tasks. Yohanes (2016), suggested that cognitive load is the mental effort that must be made in working memory to process the information received.

Sweller (2011), developed Cognitive Load Theory (CLT) based on the cognitive architecture which contains working memory with visual information processing unit and audio information

processing. Distinguishes the sources of cognitive load into: 1) intrinsic cognitive load, 2) extrinsic cognitive load and 3) Germane cognitive load. Intrinsic cognitive load is the mental load experienced by students during learning caused by the level of complexity of the material, extrinsic cognitive load is a mental load experienced by students during learning caused by the way the material is presented that is not well designed making it difficult students' understanding, while the germane cognitive load is the mental load experienced by students during learning caused by cognitive processes that are relevant to understanding the material being studied and the construction process or schematic acquisition.

Furthermore, one alternative in overcoming students' mathematical anxiety is to minimize students' cognitive load in learning. Minimizing students' cognitive load can be done by presenting more simple questions. Methods to minimize extrinsic cognitive load include avoiding the effects of separate attention. The effect of separate attention is caused by the presentation of two sources of information separately, but in order to understand it, the information must be integrated (Retnowati, 2008). Such as providing questions that are presented in an integrative way between images and associated text (verbal or written) will make it easier for students to understand the problem.

Minimizing cognitive load can also be done by teachers by using media or software as a tool in the learning process. One of the alternative media for learning mathematics is the Autograph application. Butler (2007), autograph is dynamic software for learning mathematics that is more effective, efficient, and fun for teachers and students, and has 2 dimensions and 3 dimensions features including statistics, probability, and coordinate geometry. Afidah (2015) stated that the use of learning media can make it easier for students to understand something abstract to be more concrete. Mayer and Moreno (2010), suggest that in order to achieve effective learning, media development must be able to manage intrinsic cognitive load, reduce extraneous cognitive load and increase germane cognitive load. Managing the intrinsic cognitive load through the presentation of the prerequisite material needed to process new knowledge. Reducing extraneous cognitive load by presenting related words and pictures at the same time and close together, as well as presenting outlines and signs in the text that can bring students' attention directly.

We think that increase the germane cognitive load by providing feedback in the form of true or false responses and explanations that direct students to obtain the required information. Furthermore, giving students the opportunity to explain the material they have learned in their own language.

Several studies related to the use of Autograph in learning mathematics (Sinaga, et al., 2018; Triana *et al.*, 2019; Sari *et al.*, 2020; Ahmadi, 2021). Further research is related to cognitive load and math anxiety (Phan, 2017; Chu, 2017; Mavilidi, 2020; Ganley, 2021). However, there are almost no

or very limited studies that use autograph media to reduce mathematical anxiety based on cognitive load theory. The difference between our research and previous research lies in the use of Autograph software to reduce math anxiety based on cognitive load theory. Therefore, the research hypothesis is that the Autograph software as media-assisted learning intervention based on cognitive load theory can reduce students' mathematical anxiety.

METHOD

This research was conducted in a Junior high school in South Tangerang City, Indonesia for the 2017/2018 academic year. The research subjects were students of class VIII-(IB) with a total of 28 students. The observer in this study was a class VIII mathematics teacher. The teacher's role is to help researchers observe student and researcher activities during the mathematics learning intervention. This research is Classroom Action Research (CAR) which was conducted in two cycles. Each cycle consists of four stages, namely planning, action, observation, and reflection. The first and second cycles were carried out in three meetings each. The research design in Figure 1.

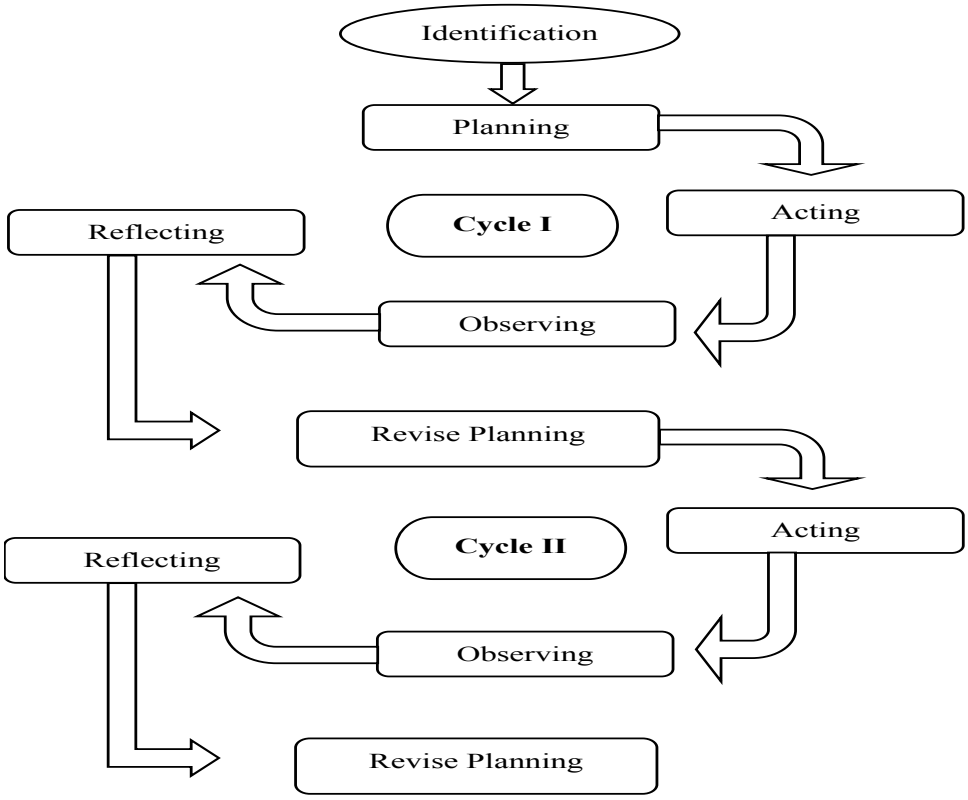

Figure 1. CAR design

Based on Figure 1, the CAR stages are explained as follows:

1. Identify the problem

At this stage, the researcher conducted observations and interviews with the teacher on actual events in the classroom, identifying and formulating problems.

2. Planning

At this stage, the researcher developed a lesson learning based on the stages of cognitive independent theory, made interview guidelines, observation sheets, daily journals, student worksheets, and mathematical anxiety scales, problem solving tests to be tested at the end of each cycle.

3. Acting

At this stage, the implementation of the design, namely carrying out learning using Autograph media based on cognitive load theory. The action plans for Cycle I and Cycle II are presented in Table 1.

Table 1. Implementation stage in Cycle I and Cycle II

Stages	Cycle I	Cycle II
Managing intrinsic cognitive load (*Pretraining, Modality, Segmenting*)	▪ The researcher presents the prerequisite material needed in processing new knowledge. ▪ The researcher presents the material for straight line equations using the Autograph media. ▪ The researcher divides the material into several sub-materials.	▪ The researcher gave a quiz about the prerequisite material needed to understand the material to be studied. ▪ The researcher instructed the students to use the Autograph media alternately with other students in one group.
Reducing extraneous cognitive load (*Spatial Contiguity, Signaling*)	▪ The researcher grouped the students into several groups, each group consisted of 4-5 people. ▪ The researcher presents pictures and words that are closely related. ▪ The researcher presents an outline and signs in the text that can bring students' attention directly.	▪ The researcher randomized the group division so that more heterogeneous groups were obtained. ▪ Researchers provide problems accompanied by graphical presentations, which make it easier for students to search and find the desired answers.
Increase the germane cognitive load (*Reflection, Application*)	▪ The researcher asked each group to conclude the material they had learned in their own language. ▪ The researcher asks each group to make another case related to the material that has been studied.	▪ The researcher asked each group to conclude the material they had learned in their own language. ▪ The researcher instructs students to make other cases individually related to the material that has been studied.

4. Observing

At this stage, the researcher along with the observer observes and records things that occur during the implementation of the action. Researchers and observers observed students' mathematical anxiety symptoms to obtain the required data.

5. Reflecting

At this stage the researcher and observer discussed and analyzed the data from the implementation of the first cycle and second cycle of actions. If the results at the end of each cycle have shown that the indicators of success have been achieved, the research is stopped.

Data collection uses test and non-test techniques, including: *Test*: a test to measure problem solving ability. *Interviews*: interviews were conducted to obtain data on the activities of the pre-research stage, the learning process, student responses to learning, and problems faced in the classroom. *Observation*: observation of students' mathematical anxiety by the observer at each meeting during the teaching and learning process in the classroom. *Questionnaire*: a questionnaire was given to all students of class VIII IB to determine the level of students' mathematical anxiety. *Daily journal*: student's daily journal to find out student responses during the implementation of the action and is given at the end of each meeting.

Trustworthiness check technique: The quality of the instrument from the aspect of validity and reliability.

Content validity:

The content validity of the MPSA test instrument was determined using the Content Validity Ratio (CVR) method from Lawshe (1975). Determination of content validity involved 8 expert panelists in the field of mathematics including 2 mathematics lecturers and 6 mathematics teachers. *CVR* formula.

$$CVR = \frac{(N_e - \frac{N}{2})}{\frac{N}{2}} \quad (1)$$

Note:
CVR = *Content Validity Ratio*
N = total number of panelist
Ne = number of panelist in indicating essential

Empirical Validity

The validity of the items on the mathematical anxiety scale and the MPSA test was obtained through instrument testing to 33 students of class VIII. Testing the validity using the product moment formula.

$$r_{xy} = \frac{N(\sum XY) - (\sum X)(\sum Y)}{\sqrt{\left[N(\sum X^2) - (\sum X)^2\right]\left[N(\sum Y^2) - (\sum Y)^2\right]}} \quad (2)$$

Note:
r_{xy}= correlation coefficient between item scores (X) and total scores (Y),
test criteria formula (2) for α = 0,05 is if $r_{xy} \geq r_{cv}$ then the item is valid and if $r_{xy} < r_{cv}$ then the item is not-valid.

Determination of the reliability of the mathematical anxiety scale and the MPSA test was carried out using the *Cronbach Alpha* formula.

$$r_{11} = \left(\frac{k}{k-1}\right)\left(1 - \frac{\sum \sigma_i^2}{\sigma_i^2}\right) \quad (3)$$

Note:

r_{11} = reliability coefficient

k = number of valid items

$\sum \sigma_i^2$ = total variance score for each item

σ_i^2 = total variance

If $r_{11} > 0.70$ from the formula (3) then the degree of instrument reliability is acceptable or reliable (Naga, 2013).

Intervention success criteria

The results of the research are expected to decrease mathematical anxiety and increase students' MPSA through learning Autograph media based on cognitive load theory. The action of each cycle is said to be successful if it meets the following criteria: (1) The average of each indicator of students' mathematical anxiety (MA) in learning decreases by 25%; (2) the results of the MPSA test at the end of the cycle reached 70% of the students' scores reached the minimum mastery criteria; (3) The average percentage of students' positive responses in Autograph-assisted learning based on cognitive load theory reaches 80%.

RESULTS AND DISCUSSION

1. The results of the validation of the mathematical anxiety scale (MA)

The results of the item validity test and the calculation of the reliability of the mathematical anxiety (MA) scale are in Table 2.

Table 2. The results of the test of the validity of the MA scale items

Indicator	Sub indicator	Items	r_{observ}	r_{tabel}	Decision
Cognitive	Difficult to concentrate	Item 01	0.05	0.34	Invalid
		Item 05	0.39	0.34	Valid
	Forget	Item 03	0.51	0.34	Valid
		Item 06	0.40	0.34	Valid
		Item 07	0.51	0.34	Valid
Emotion	Afraid	Item 09	0.55	0.34	Valid
		Item 10	0.30	0.34	Invalid
		Item 16	0.59	0.34	Valid
		Item 17	0.43	0.34	Valid
	Tense	Item 12	0.65	0.34	Valid
		Item 13	0.53	0.34	Valid
		Item 20	0.46	0.34	Valid
	Nervous	Item 08	0.40	0.34	Valid
		Item 15	0.20	0.34	Invalid
		Item 22	0.27	0.34	Invalid
Physiological	Heart beat	Item 18	0.39	0.34	Valid
		Item 21	0.05	0.34	Invalid
		Item 24	0.62	0.34	Valid
		Item 25	0.69	0.34	Valid
		Item 26	0.58	0.34	Valid
	Dizzy	Item 02	0.35	0.34	Valid
		Item 28	0.40	0.34	Valid

Nausea	Item 04	0.45	0.34	Valid
	Item 19	0.50	0.34	Valid
	Item 23	0.39	0.34	Valid
Stuttering voice	Item 11	0.58	0.34	Valid
Body shaking	Item 14	0.61	0.34	Valid
	Item 27	0.48	0.34	Valid
Reliability coefficient (valid items)				0.87

The results of the analysis in Table 2, reveal that there are 23 valid items with a Cronbach Alpha reliability coefficient of 0.87 or classified as high criteria. Thus the scale can be used to capture mathematical anxiety scale (MA) data.

2. The results of the validation of the mathematical problem solving ability (MPSA) test

The results of the content validity and empirical validity of the MPSA test, Table 3.

Table 3. The results of the content validity test and the validity of the MPSA items

Indicators	Item	CVR Value	Minimum CVR	$r_{observe}$	r_{tabel}	Decision
1. Understanding the problem	Item 01	0.75	0.75	0.75	0.34	Valid
	Item 02	0.75	0.75	0.25	0.34	Invalid
2. Devising a plan	Item 03	0.75	0.75	0.63	0.34	Valid
3. Carrying out the plan	Item 04	1.00	0.75	0.60	0.34	Valid
4. Looking back	Item 05	1.00	0.75	0.65	0.34	Valid
	Item 06	1.00	0.75	0.61	0.34	Valid
	Item 07	1.00	0.75	0.63	0.34	Valid
	Reliability coefficient (valid items)					0.73

The results of the analysis in Table 3, reveal that 6 items are valid with a reliability coefficient of r_{11} = 0.73 or classified as high criteria. Thus, the instrument can be used to collect mathematical problem solving ability data.

3. Cognitive load

The percentage of students' cognitive load at the pre-cycle stage is presented in Figure 2.

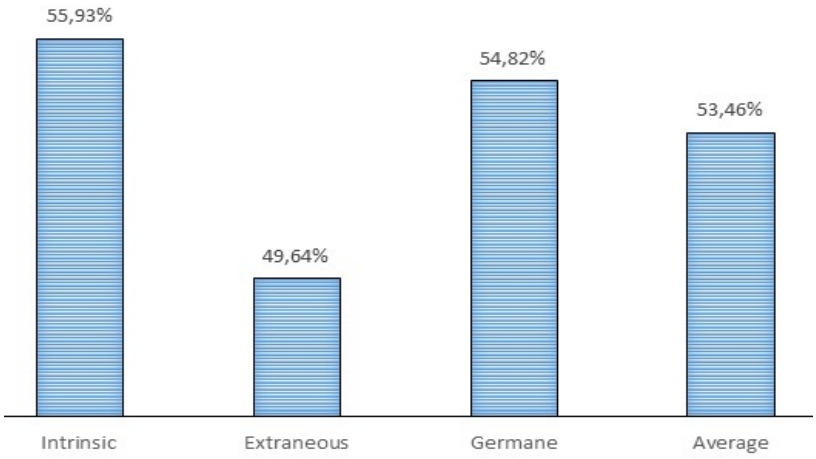

Figure 2. Percentage of students' cognitive load at the pre-cycle stage

Figure 2 shows that overall, students' cognitive load in the pre-cycle or before the action is quite high (> 50%). Based on three aspects of cognitive load, the percentage of intrinsic aspects is the highest, then extraneous and the lowest is the germane aspect. Theoretically, this research intends how to manage intrinsic cognitive load, decrease extraneous, and increase germane cognitive load. Especially the increase in germane cognitive load is closely related to the increase in students' mathematical problem solving ability.

4. Student math anxiety

Data on students' mathematical anxiety (MA) in the pre-cycle, cycle I, cycle II in Figure 3.

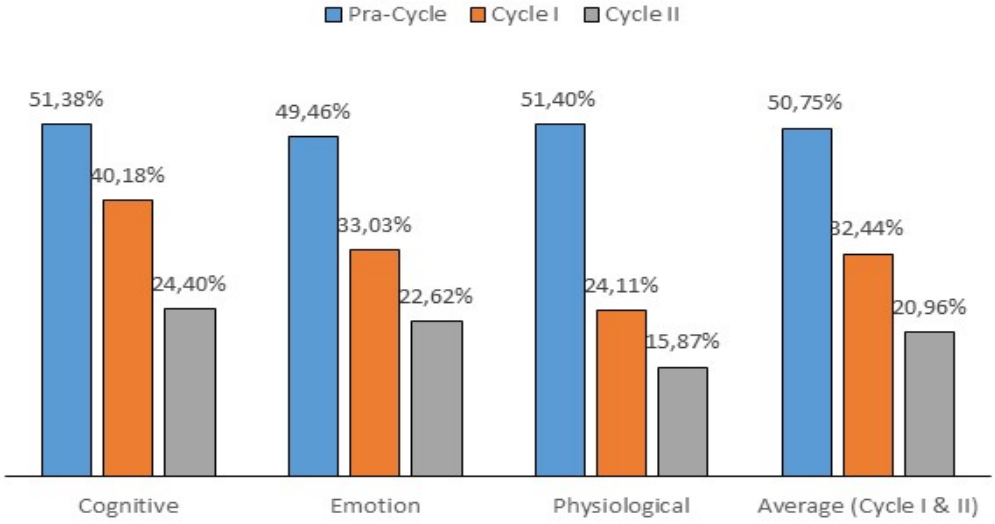

Figure 3. Students' mathematical anxiety (MA) in the pre-cycle, cycle I and cycle II

Based on the results of the analysis in Figure 3, it shows that in general, mathematical anxiety has decreased which is classified as good from the pre-cycle (50.75%), to the first cycle (32.44%) and finally in the second cycle (20.96%). Based on the indicators of mathematical anxiety, it can be seen that in cycle II, anxiety in terms of cognitive, emotional, and psychic anxiety decreased which was classified as good from pre-cycle, cycle I, and to cycle II. This decrease in mathematical anxiety is already below the maximum criteria for anxiety, which is 25%. This finding revealed that the Autograph media-assisted learning intervention based on cognitive load theory was able to reduce students' mathematical anxiety levels, both overall anxiety and based on indicators of cognitive, emotional, and psychological anxiety. The finding of a decrease in students' mathematical anxiety in this study is in line with the findings of previous studies that suggest that reducing extraneous cognitive load can reduce students' stress or anxiety (Gillmor & Embretson, 2015).

5. Mathematical problem solving ability (MPSA)

A summary of the results of student MPSA analysis in Cycle I and Cycle II d in Table 4.

Table 4. MPSA test results in Cycle I and Cycle II

Statistics	Cycle I	Cycle II
Minimum score	33.33	50.00
Maximum score	90.00	93.33
Average score	64.36	73.93
Student mastery (≥72)	53.57%	71.43%
Student not mastery (<72)	46.43%	28.57%

The results of the analysis in Table 4, reveal that overall, the average MPSA score for mathematics subjects increased from 64.36 in Cycle I to 73.93 in Cycle II. Student mastery in Cycle II has reached > 70% of students who get a score of 72.

Graphically, the MPSA mastery scores of 28 students based on the minimum mastery criteria of 72 are presented in Figure 4.

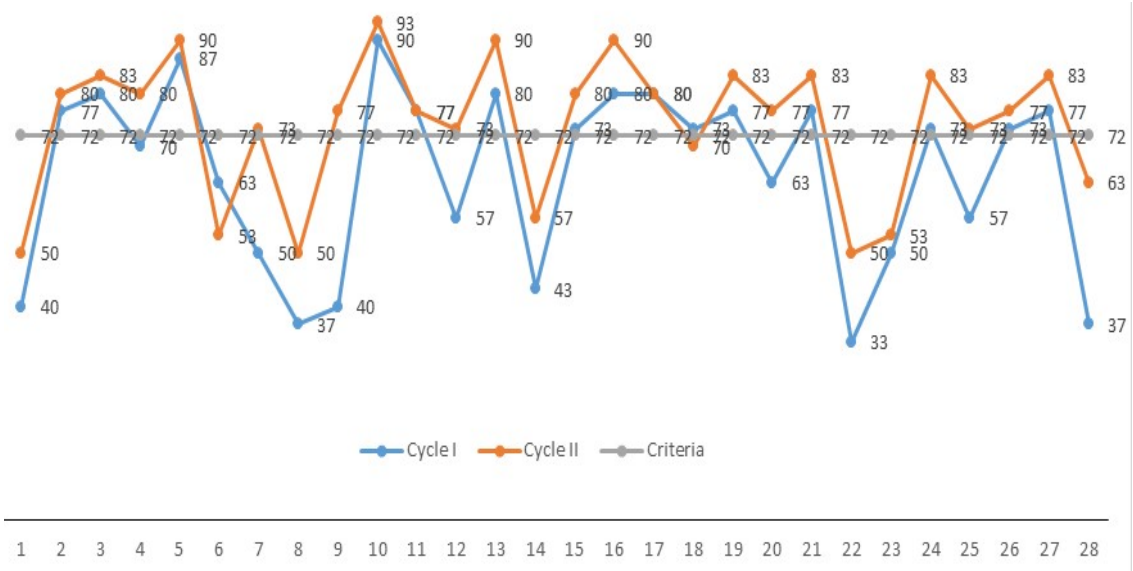

Figure 4. Students' MPSA scores based on the minimum mastery criteria of 72

The results of the analysis in Figure 4, show that of the 28 students who participated in the Autograph media-assisted learning based on cognitive load theory, as many as 20 students (71.43%), obtained a math problem-solving ability score that exceeded the mastery criteria of 72. The findings of this study reveal that, in general, Autograph software based on cognitive load theory is actually able to improve students' mathematical problem solving abilities (MPSA).

Furthermore, the average students' MPSA score at the end of Cycle I and Cycle II according to indicators is presented in Figure 5.

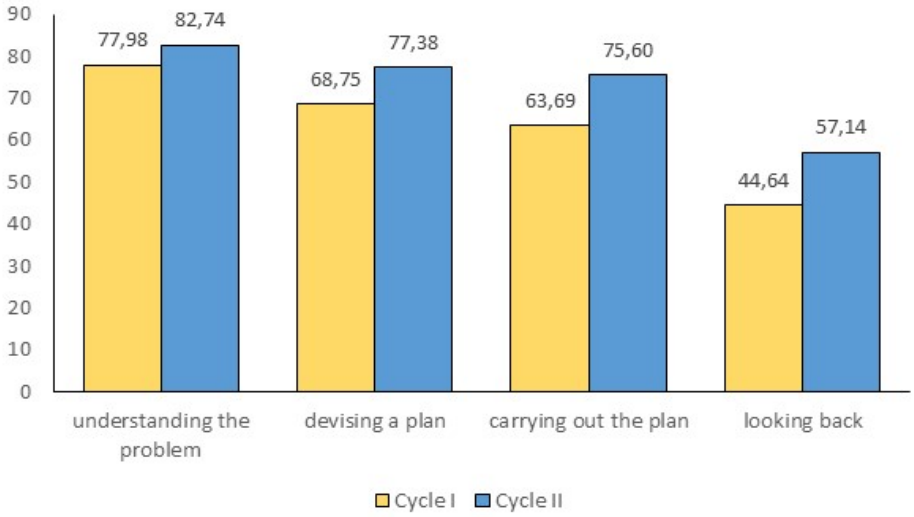

Figure 5. The average MPSA- indicators score of students at Cycle I and Cycle II

Based on the analysis in Figure 5, it shows that except for indicators looking back, the indicator of understanding the problem, devising a plan, and carrying out the plan indicators have increased which are classified as good from Cycle I to Cycle II. The achievement of the MPSA score in Cycle II has exceeded the minimum mastery criteria that have been set, which is > 75%. The findings of increasing students' mathematical problem solving ability test results in this study are in line with the research findings of Damayanti (2013), that multimedia can be used to manage intrinsic load, reduce extraneous cognitive load, and increase germane cognitive load, so as to improve students' ability to solve problems. In this case, there are similarities in learning, namely the use of media in the learning process. At the stage of managing intrinsic cognitive load, students use Autograph media to solve the problems presented. In addition, students also use the Autograph media to re-examine the answers obtained.

6. The relationship between mathematical anxiety (MA) and MPSA

To explain the relationship between mathematical anxiety and MPSA, a regression test was conducted. The results of the regression test are presented in Table 5.

Table 5. MPSA (Y) Regression Results on MA (X) on Cycle I and Cycle II

Cycle	Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
Cycle I	Constant	99.803	8.437		11.829	.000
	MA	-.696	.160	-.649	-4.350	.0002
Cycle II	Constant	129.784	13.953		9.302	.000
	MA	-1.983	.491	-.621	-4.037	.0004

Dependent Variable: MPSA

Based on the results of the analysis in Table 5, the regression equation for the first cycle: $\hat{Y} = 99.803 - 0.696X$ and the second cycle regression equation: $\hat{Y} = 129.784 - 1{,}983X$. Furthermore, the statistical value of the t-test regression coefficient for Cycle I was -4.350 (p-value = 0.0002 < 0.05) and Cycle II was -4.037 (p- value = 0.0004 < 0.05). This means, research findings in both Cycle I and Cycle II, reveal that students' mathematical anxiety has a negative effect on mathematical problem solving abilities. Thus, the lower the level of students' mathematics anxiety, the higher the achievement of problem solving abilities that can be obtained by students. The findings of this study are relevant to the research of Kurniawati (2014), that mathematical anxiety has a negative relationship to mathematical problem solving abilities, which means that the lower a person's mathematical anxiety level, the higher his mathematical problem solving ability.

7. Student Response

Data on student responses to Autograph software as media-assisted learning based on cognitive load theory were obtained from daily journals. The average percentage of student responses during the learning Cycle I and Cycle II is presented in Figure 6.

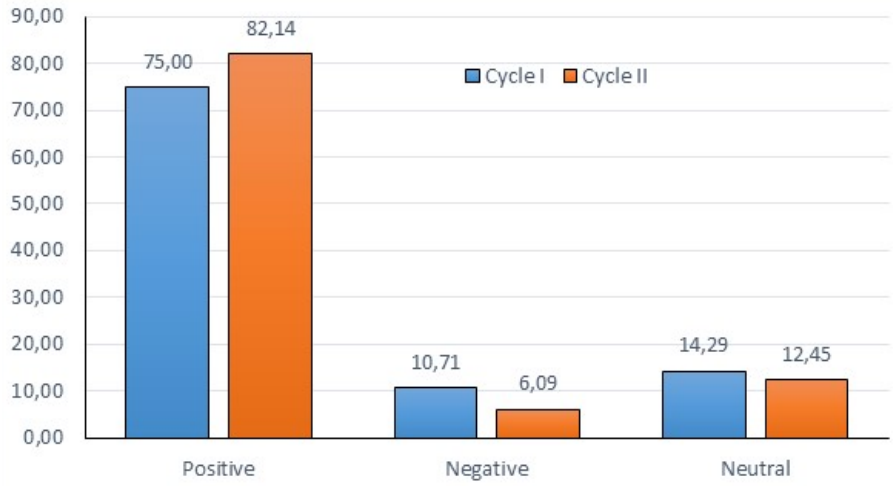

Figure 6. Student responses to learning interventions

Based on Figure 6, it can be seen that the positive response of students to Autograph software based on cognitive load theory has increased from cycle I to cycle II. An increase in positive responses of 7.14% and a decrease of 4.62% and 1.84% respectively in students' neutral and negative responses to the learning. This shows that Autograph software based on cognitive load theory can increase students' positive responses. Students with positive responses, generally in group discussions have more freedom to process the available information. The learning process using Autograph software equipped with worksheets makes students more enthusiastic in learning, and makes it easier for students to understand the material provided. This finding is in line with research conducted by Simanjuntak (2016), which found that mastery of the use of Autograph

media can increase the creativity of mathematics educators and create a pleasant atmosphere and attract students' interest in learning mathematics.

CONCLUSION

The application of Autograph software as media-assisted learning based on cognitive load theory can reduce students' mathematical anxiety. Students' mathematical anxiety can be reduced through study group activities, giving time lag for students to understand the material, asking questions, and writing, giving rewards to the most active groups, and motivating all students during learning.

Autograph software based on cognitive load theory can improve students' mathematical problem solving abilities. The lower the level of anxiety, the higher the mathematical problem solving ability that can be obtained by students (t =-4.350; p-value=0.0002) Cycle I and cycle II (t = -4.037; p-value=0 ,0004).

In general, students' positive responses experienced an increase in Autograph software based on cognitive load theory. Most of the students said that Autograph software learning was more fun with group learning. However, some responded negatively stating that they prefer to be explained directly because they are not familiar with the learning method and the questions given by the teacher.

ACKNOWLEDGMENTS

Thank you to the Faculty of Education, UIN Syarif Hidayatullah Jakarta for the support of the publication program in nationally accredited journals during the Covid-19 pandemic, as well as to lecturer colleagues in the mathematics education department who have provided motivation and academic support to us for the progress of this paper.

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