Biosfer: Jurnal Pendidikan Biologi

Journal homepage: http://journal.unj.ac.id/unj/index.php/biosfer

Pre-services biology teachers: correlation of metacognition awareness with the ability to design experiments through vee diagram

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ARTICLE INFO

Article history
Received: 3 October 2019
Revised: 24 January 2020
Accepted: 12 April 2020

Keywords:
Ability to design experiments
Metacognition awareness
Pre-services
Vee Diagram

A B S T R A C T

Practice plays a role in explaining theory through the form of laboratory activities. Practice in the form of investigation, such as designing experiments, is a form of practice that focuses on the thought thinking process compared to the verification practice. Designing experiments in the form of the Vee diagram are a practice that develops the thought process and metacognition awareness, and it has been one of the factors associated with design experiments. This study aimed to analyze the correlation of metacognition awareness towards the ability to design experiments that are outlined in the form of a Vee Diagram. The method used was correlational research that measured the relationship between metacognition awareness indicators. It consisted of declarative knowledge, procedural knowledge, limited knowledge, and cognition regulation with the ability to design experiments. The sampling technique used purposive sampling with 28 students of the third semester of a private university in Kuningan. Instruments in this study consisted of the Vee Diagram rubric and the Metacognitive Awareness Inventory (MAI) for metacognition awareness. The results showed that there was a correlation between declarative knowledge, procedural knowledge, limited knowledge, and cognition regulation simultaneously with the ability to design experiments by 63.4%. The remaining 36.6% came from other factors.

Handayani., & Widiantie, R. (2020). Pre-services biology taeachers: correlation of metacognition awareness with the ability to design experiments through vee diagram. *Biosfer: Jurnal Pendidikan Biologi, 13*(1), 143-154. https://doi.org/10.21009/biosferjpb.v13n1.143-154

INTRODUCTION

Practice plays a vital role in science education, especially in Biology education. The benefits that can be obtained in practice is that students can apply the obtained theory in a form through laboratory activities (Ali & Arif, 2019; Suryanda, Rusdi, & Kusumawati, 2017). Practice activities in the laboratory are very different from classroom learning activities (Inayah, Ristanto, Sigit, & Miarsyah, 2020; Hindriana, 2016). Biology education activities in the laboratory use more time and more activities, such as using tools and materials to complete the practice objectives (Bahtiar & Dukomalamo, 2019). If students do not understand the purpose of the practice, they will not benefit from the laboratory activities. Regardless of the benefits of the work laboratory, students labs rarely focus on practice objectives, students only try to determine the results that have been expected, so students do not try to link the correlation between laboratory work and other learning experiences.

Practice in the laboratory often cognitively loads students with too many things to remember (Hudha, 2011; Ismirawati, et al., 2020). Work-lab can be successfully carried out to encourage conceptual change if laboratory activities focus on the qualitative process in terms of focusing their thinking processes (Hindriana, 2016, Hudha, 2011). This work lab helps to reconstruct students' thinking because it spends less time interacting with laboratory instruments, work procedures, and practice manuals and spend more time on discussion and reflection (Hart et al., 2000). Practices that tend to be directed by the teacher in the form of recipe books often fail to connect between practice and other aspects of learning or concepts that they obtain during the learning process (Ali & Arif, 2019; Bahtiar & Dukomalamo, 2019). Verification laboratory activities, according to Van Heuvelen (2001), McDermott, Shaffer, & Constantinou (2000), does not help much in developing thinking skills. Hart et al. (2000) found that discussion was a very effective method of making laboratories as an active learning environment. Meaningful discussions help students clarify their thoughts (Ristanto & Djamahar, 2019). It can happen if students carry out scientific investigations.

One of the scientific investigations done by students in practical activities is through design experiments (Djamahar, et al., 2019). The experimental design that can facilitate students in the discussion activities is through the Vee Diagram. Vee diagrams as tools that play a role in guiding work laboratory facilitate learning and reflective thinking as planned and done in scientific investigations (Novak & Gowin, 1984). Vee Diagrams help in the thought process by acting as a metacognition tool that demands to make explicit connections between previously learned information and the new ones through scientific inquiry (Alvarez & Risko, 2007).

One of the correlating factors in design experiments is metacognition awareness. Metacognition is knowledge related to cognitive processes, including self-regulation, namely the ability to manage learning processes such as planning, monitoring success, and correcting errors to achieve active learning (Djamahar, et al., 2019; Lestari, Ristanto, & Miarsyah, 2019; Tanner, 2012). Metacognition consists of two major components: knowledge about cognition and regulation of cognition (Pratama, 2018: Darmawan, Brasilita, Zubaidah, & Saptasari, 2018). Knowledge about cognition are declarative knowledge, procedural knowledge, and limited knowledge (Musyaddad & Suyanto, 2019). Regulation of cognition is categorized as planning, information management strategies, comprehension monitoring, debugging strategies, and evaluation (Darmawan, Brasilita, Zubaidah, & Saptasari, 2018; Schraw & Dennison, 1994). The experimental design, as outlined in the form of a Vee Diagram, is a tool that accommodates student metacognition awareness (Novak, 1990). Vee Diagram is a metacognition tool that requires students to make connections between information the obtained previously, namely when lectures with new information are obtained through scientific investigation in the form of practice (Alvarez & Risko, 2007). The Vee diagram's conceptual side is the basis of the experimental design they obtained after the lecture. The focus questions that outlined in the

Vee Diagram is a problem that will find a solution through scientific investigation (Cuevas, Fiore, & Oser, 2002; Novak, 1990). The solutions obtained are outlined on the methodology side of the Vee Diagram. This stage is a scientific process that leads students to their metacognition abilities (Djamahar, et al, 2019). Metacognition awareness that comes in design experiments is evaluating the reasoning of other group members, evaluating their understanding abilities, evaluating the plans that they made, and evaluating work laboratory procedures (Lippman, 2005; Darmawan, Brasilita, Zubaidah, & Saptasari, 2018). The implementation of the practice, which begins with design experiments, allows students to entirely control what they do in the laboratory. This is where metacognition awareness plays a role in supporting the students' ability of design experiments in the form of planning, monitoring and reflecting cognitive learning strategies so that students can interact with their groups and reflect on experiments that they designed. This study aimed to analyze the relationship between declarative knowledge, procedural knowledge, limited knowledge, and cognition regulation on the ability to design experiments through Vee Diagrams.

METHODS

Research Design

The research method used in this research is the correlational research design. There are two correlational research variables, namely the independent variable and the dependent variable. The independent variable in this study was metacognition awareness consisting of declarative knowledge (X1), procedural knowledge (X2), conditional knowledge (X3), and cognition regulation (X4). In contrast, the dependent variable was the ability to design experiments in the form of Vee diagrams. The resulting correlation coefficient indicated the degree of relationship between metacognition awareness and the ability to design experiments. The study was conducted for three months in the 2017/2018 school year.

Population and Samples

The study population was pre-service teacher of the Department of Biology, Universitas Kuningan, Indonesia. The sample of this study was 28 students of the third semester Department of Department of Biology, Universitas Kuningan, Indonesia who were taking Biochemistry lectures in the odd semester of 2017-2018. The sample selection in this study used the purposive sampling technique.

Instrument

Data in this study were collected through the MAI (Metacognitive Awareness Inventory) developed by Schraw & Dennison (1994) for awareness of metacognition and the Vee Diagram rubric for the ability to design experiments. The MAI instrument consisted of 52 statement items, and the grading diagram was assessed using a scale consisting of 4 scales.

Procedure

The study had been conducted for three months, with three stages. The first stage was the introduction of vee diagrams. The second stage was designing experiments with guidance through vee diagrams. Lastly, the third stage students designed experiments independently through vee diagrams. Assessment of the ability to design experiments using the vee diagram rubric was done at the end of each stage. In contrast, the assessment of students' metacognition awareness was carried out at the end of the third stage.

Data Analysis Techniques

The collected data were analyzed using Pearson Correlation and multiple linear regression analysis. Pearson Correlation was used to determine whether there was a correlation between each metacognitive awareness indicator towards the ability to design experiments. Meanwhile, multiple linear regression was used to predict the ability of design experiments to predict variables (declarative knowledge, procedural knowledge, limited knowledge, and cognition regulation). The significance level used in the analysis was 5%.

RESULTS AND DISCUSSION

The results show that each of the four metacognitive awareness indicators does not correlate with the ability to design experiments. It shows that the predictor variable partially does not correlate with the ability to design experiments. The test results for each metacognitive awareness correlation indicate the ability to design experiments, as shown in Table 1.

Table 1

Partial correlations about metacognition awareness.

Indicator of Metacognition Awareness	Pearson Correlation	Sig
Declarative knowledge	0,024	>0,05
Procedural knowledge	0,031	>0,05
Conditional knowledge	0,335	>0,05
Cognition regulation	0,180	>0,05

The correlation of metacognition awareness indicators simultaneously with the ability of design experiments gives significant correlations, as presented in Table 2. There are three models of correlations between metacognitive awareness indicators and the ability to design experiments. The first model correlates with four predictors variables (declarative knowledge, procedural knowledge, conditional knowledge, and cognition regulation). The second correlates with three predictor variables (declarative knowledge, conditional knowledge, and cognition regulation), and the third model correlates with two predictor variables (conditional knowledge and regulation of cognition). The first model was chosen because it has the most predictor variables and has the most significant effect of 63.4% on the ability to design experiments. It indicate that other factors outside the predictor variable influence 36.6 %.

Table 2

Simultaneous correlations of metacognition awareness.

Model	Indicator of Metacognition Awareness	R Square
1	Declarative knowledge, procedural knowledge, conditional knowledge, and cognition regulation.	0,634
2	Declarative knowledge, conditional knowledge and cognition regulation.	0,630
3	Conditional knowledge and cognition regulation.	0,607

The linear model between declarative knowledge, procedural knowledge, conditional knowledge, and cognition regulation with the ability of design experiments shows the significance of the regression equation F = 3,868 with significance < 0.05 (Table 3). It indicate that the regression models of the four independent variables can predict the ability of design experiments.

The regression first model can be used to create a regression equation that describes the relationship of the four independent variables (metacognition awareness) to the dependent variable (ability to design experiment), as presented in Table 4. The results indicate that the equation $Y = 84{,}774 - 0{,}082X1 + 0{,}024X2 + 0{,}304X3 - 0{,}437X4$ can predict the dependent variable.

Table 3
Independent variable regression model on the ability to design experiment.

Model		Sum of Square	df	Mean Square	F	Sig
1	Regression	612,959	4	153,240	3,868	<0,05
	Residual	911,148	23	39,615		
	Total	1524,107	27			

Table 4
Independent variable regression coefficient model on the ability to design experiment

Model		Unstandardized Coefficient		Standardized Coefficient	t	Sig
		B	Std. Error	Beta		
1	(Constant)	84,774	9,692		8,747	<0,05
	Declarative knowledge	-0,082	0,075	-0,251	-1,009	<0,05
	Procedural knowledge	0,024	0,057	0,083	0,428	<0,05
	Conditional knowledge	0,304	0,083	0,882	3,640	<0,05
	Cognition regulation	-0,437	0,158	0,642	-2,772	<0,05

The Correlation of Partial Metacognition Awareness Indicators

Based on the hypothesis test of partial metacognition awareness indicators, there is no correlation between declarative knowledge, procedural knowledge, conditional knowledge, and cognition regulation partially due to the ability to design experiments. Practice implementation through design experiments requires students to fully control what activities will be carried out in the laboratory. Students are asked to plan strategies that will be used before starting the practice, taking experimental data, and drawing conclusions. The metacognition awareness has a role in supporting students' ability to design experiments through planning, monitoring and reflecting cognitive learning strategies, so that they can interact with their groups and reflect on experiments they have designed. This process helps students to control their learning process and become independent learners by relying on planning, monitoring, and evaluating their learning processes (Hofstein & Lunetta, 2004). The process carried out by the students contained declarative knowledge, procedural knowledge, conditional knowledge, and regulation of cognition, which each contributed together in design experiments. Therefore, the indicator of awareness of metacognition will not affect if only one indicator plays a role in design the experiment.

Metacognitive awareness guide students to plan, sequence, and monitor their learning by developing their performance directly (Djamahar et al., 2019; Darmawan, Brasilita, Zubaidah, & Saptasari, 2018; Handel, Artelt & Weinert, 2013). Metacognitive behavior evaluates other students' reasoning, evaluates their understanding, and evaluates laboratory procedures (Pratama, 2018; Lippman, 2005) through rearranging the vee diagram. When design experiments, students become aware of cognitive structures and manage their cognitive (Musyaddad & Suyanto, 2019; Celiker, 2015). Declarative knowledge develops through the selection of questions as the basis of the problem needs to be supported by procedural knowledge. The development is done by determining the questions that lead to conclusions in the focus of the question. This process is carried out as the beginning of design experiments, which then which then developed by planning and implementing practice as a form of regulation of cognition. It ends by concluding a form of conditional knowledge so that indicators of awareness of metacognition are interrelated with one another and cannot stand alone.

Students' metacognition awareness can be developed through their skills in identifying variables (Lestari, Ristanto, & Miarsyah, 2019), design experiments (Darmawan, Brasilita, Zubaidah, & Saptasari, 2018; Djamahar, et al., 2019), and other operational skills that are more structured compared to practices such as recipe books (Saribas & Bayram, 2009). Metacognition awareness can provide a positive effect in discussing each stage of the experiment with other group members, making questions about problems related to the practice topic, and getting feedback from the implementation of experiments (Musyaddad & Suyanto, 2019; Celiker, 2015). If students are accustomed to developing metacognitive awareness about the goals and benefits of the strategies they use, they will likely be able to generalize the strategy to new situations.

The Correlation of Simultaneous Metacognition Awareness Indicators

The results show that the correlation of metacognition awareness indicators towards the ability to design experiments simultaneously have known that there is a correlation between declarative knowledge, procedural knowledge, conditional knowledge and cognition regulation with the ability to design experiments. The decreasing correlation shows that the more complete metacognition awareness indicators developed, the higher the contribution to the ability to design experiments. The smaller significance values indicate which metacognitive awareness indicators together influence the ability to design experiments. Conditional knowledge indicators and cognition regulation are metacognition awareness indicators that together have the most influence on the ability to design experiments.

The correlation between declarative knowledge, procedural knowledge, conditional knowledge, and cognition regulation towards the ability to design experiments has the highest correlation value. The four metacognition awareness indicators play a role in design experiments in the form of vee diagrams. The vee diagrams determined the headlines questions such as fundamental determination values, basic theories and concepts, hypotheses, work planning procedures, experimenting, and discussing the results of the experiment that are outlined in the form of data transformation to obtain conclusions and value claims (Cuevas, Fiore, & Oser, 2002; Novak, 1990). Most of the vee diagram processes in design experiments are an integral part of scientific investigations in the laboratory. Students practice metacognition skills when students design experiments through vee diagrams in the form of scientific investigations. According to the opinion of Kipnis & Hofstein (2008) that the metacognitive skills developed in design experiments are asking questions, instruted monitoring tasks, evaluating, justifying opinions, suggesting new procedures, and planning strategies before starting. When students participate in laboratory investigation activities, they must act according to their desires by developing metacognition (Ali & Arif, 2019; Suryanda, Rusdi, & Kusumawati, 2017). It is assumed that during laboratory inquiry learning, they can practice and develop metacognitive skills.

The four indicators of metacognition awareness developed in the form of Vee diagrams are each drawn at the stage of designing the experiment. In designing cognitive knowledge, experiments consisting of declarative knowledge, procedural knowledge, and conditional knowledge are reflected in discussion activities by asking appropriate questions and operating investigations. While the regulation of cognition must be expressed during the design of the experiment while performing it and evaluating the result regarding the assumption (Pratama, 2018; Kipnis & Hofstein, 2008). Design experiments that develop these four indicators of metacognition awareness contain planning, monitoring, and evaluation activities. The planning phase involves setting goals. The monitoring stage deals with understanding the tasks that have been carried out, and the evaluation phase involve checking the goals and conclusions (Mutai, Changeiywo & Okere, 2014).

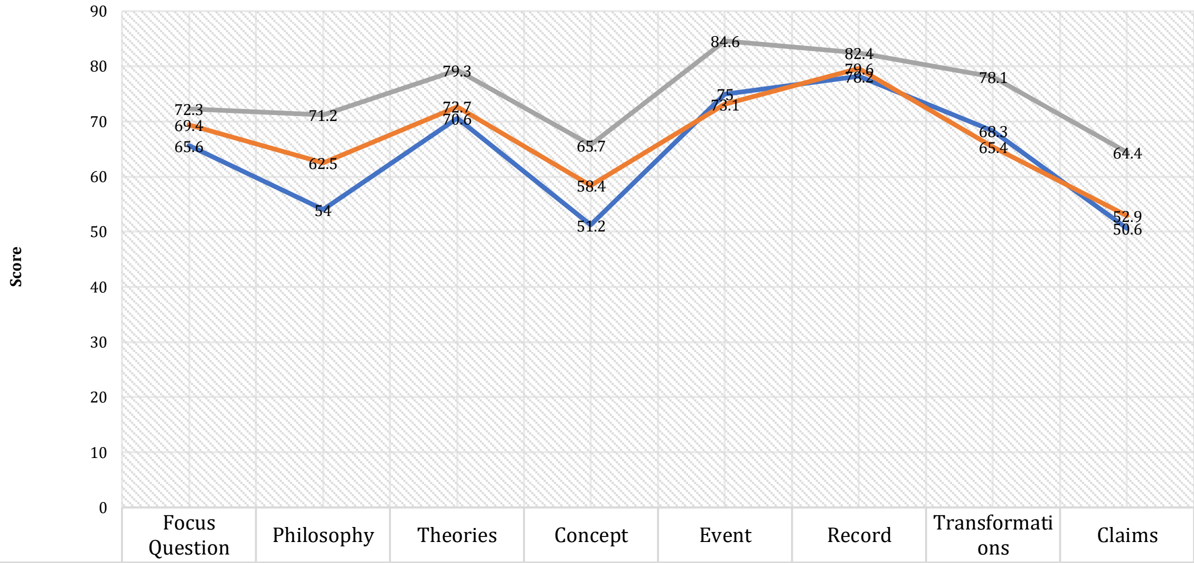
Declarative knowledge is factual knowledge needed by learners before processing or using critical thinking (Schraw & Dennison, 1994). The indicator is the indicator determines what strategies students will use in learning. In designing experiments, declarative knowledge is needed in determining the focus of the problem, as outlined in the form of questions. Procedural knowledge is knowledge about how declarative knowledge is used to complete a learning process or activity (Schraw & Dennison, 1994). Designing the experiment around this indicator is needed to apply knowledge to answer the focus of the questions from the experiment. This process is outlined in the form of basic concepts that will lead to hypotheses. Conditional knowledge is knowledge about when declarative knowledge is used, and when students design this knowledge experiment, students need to determine whether the chosen strategy is appropriate to answer the problem. Regulation of cognition indicators that contain planning, monitoring, and evaluation are processes reflected in designing experiments—starting from setting practicum objectives to determine new strategies if it finds errors in answering problems. Students who have a high awareness of metacognition will use many strategies to correct their mistakes (Suratno, 2011). When students use various strategies or use their metacognitive skills, they will observe the experiments they have designed, and the lecturer's feedback will help increase their motivation. Therefore, creating metacognitive awareness can make laboratory learning more useful (Saribas & Bayram, 2009).

The experimental design in the form of a vee diagram consists of two sides, namely the conceptual side and the methodological side. On the conceptual side, students develop students' fundamental knowledge in the form of basic values, theoretical basis, basic concepts, and methods as the basis of experimental design. In contrast, on the methodological side, students apply practical implementation in the form of observations, data transformations, evaluations, and value claims. This vee diagram allows students to make a connection between theoretical knowledge that will be learned with the future work lab. The concept section and activities interact through objects or events that learned to answer the headline's question (Novak & Gowin, 1984). The process of linking or making correlation is a form of declarative knowledge and conditional knowledge. Metacognitive activities are related to procedural knowledge and cognition regulation (Kipnis & Hofstein, 2008).

When determining the headline's question, students ask questions and choose questions from their group colleagues. They express their thoughts about the questions suggested by their group colleagues. At this stage, declarative knowledge is developed. Procedural knowledge develops when students choose questions headlines questions based on the chosen questions, which are leading to conclusions. Planning experiments and accomplish experiments train to develop student cognition regulation while making conclusions, and writing lab reports can develop conditional knowledge (Indriani & Mercuriani, 2019; Hindriana, 2016, Hudha, 2011). Therefore, when accomplishing a laboratory investigation that begins to design an experiment, cognition knowledge consisting of declarative knowledge, procedural knowledge, and conditional knowledge must be reflected during the group discussion process about determining suitable the headlines questions for the investigation (Lestari, Ristanto, & Miarsyah, 2019). Cognition regulation must also appear during planning experiments, carrying out experiments, and evaluating results (Hudha, 2011; Ismirawati, et al., 2020). Through cognition regulation, students can determine strategies that are not appropriate and improve them by determining new strategies (Sele, 2019; Kipnis & Hofstein, 2008). This can be seen in the increase of the vee diagram score for each component (Figure 1). Based on the significance value, conditional knowledge and cognition regulation are the most crucial indicator of metacognition awareness. It is seen in the average value of the vee diagram component that is higher than the other.

The application of vee diagrams in the experiments form can improve student metacognition awareness (Cuevas, Fiore, & Oser, 2002; Novak, 1990; Novak & Gowin, 1984), and the vee of diagrams constructed by students over time would increase (Afamasaga-Fuata'i, 2009) where vee diagrams can display student metacognition during the acquisition of new knowledge with knowledge that is related or previously possessed knowledge (Vanhear &

Johnston, 2006). Vee diagrams developed based on the form of design experiments can improve thinking skills. Using the vee diagrams facilitate students to build cognitive schemes that enable them to acquire holistic knowledge through the correlation between conceptual material that is being studied with relevant fields of study, and also facilitate the use of several cognitive processes (Musyaddad & Suyanto, 2019; Celiker, 2015; Hindriana, 2016).



	Focus Question	Philosophy	Theories	Concept	Event	Record	Transformations	Claims
VEE I	65.6	54	70.6	51.2	75	78.2	68.3	50.6
VEE II	69.4	62.5	72.7	58.4	73.1	79.6	65.4	52.9
VEE III	72.3	71.2	79.3	65.7	84.6	82.4	78.1	64.4

Figure 1. A score of vee diagram.

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Laboratory learning in the form of design experiments is one example of a self-regulated learning model (Bruckermann, Ascherman, Bresges, & Schlüter, 2017; Suryanda, Rusdi, & Kusumawati, 2017) that combines components that define goals, planning, acting, and evaluating. Defining objectives developed in the form of generating questions as problems to be solved, poured in the form of hypotheses, and tested through experiment. The planning phase is done by design experiments to prove the hypothesis made. In the implementation stage, the experiment is carried out to realize the experimental design and answer the hypothesis. Finally, in the evaluation phase, the experimental results are interpreted for conclusions. The self-regulated model resolves the strategy of learning metacognition by providing a meta-perspective on learning. The self-regulated model is proven efficient for the scaffolding process of the use of metacognition because it produces metacognitive activities in determining goals, planning, acting, and evaluating the learning process and functions as a matrix for the orientation and internalization of the learning process (Djamahar, et al., 2019; Lestari, Ristanto, & Miarsyah, 2019; Bruckermann, Ascherman, Bresges, & Schlüter, 2017).

CONCLUSION

Based on the results of the study, there is a correlation between the metacognition indicators simultaneously with the ability to design experiments. Where metacognition awareness indicators that together with the most influence, the ability to design experiments are conditional knowledge and regulation of cognition. Besides that, there is no correlation between the metacognition awareness indicators, respectively, with the ability to design experiments. In designing experiments, metacognition awareness is developed from knowledge of cognition consisted of declarative knowledge, procedural knowledge, and conditional knowledge. Folowed by reflecting before the discussion process of designing experiments and regulation of cognition is reflected during the designing of experiments.

ACKNOWLEDGMENT

The authors would like to are very grateful to Universitas Kuningan, Indonesia for funding support for conducting this research (No. 314/UNIKU-KNG/PP/2018).

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