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Instrument development design for metacognitive determination in calculus problem solving

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G A D Sugiharni

Sistem Informasi, Institut Teknologi dan Bisnis STIKOM Bali, Indonesia

Corresponding author : ayu_dessy@stikom-bali.ac.id

Abstract. This research main objective was to produce an instrument development design for metacognitive determination in calculus problem solving. This study used a development approach with the research and development method. The subjects involved in this study were two psychologists and three education experts. Observation, interviews, literature study and documentation, those were data collection techniques used in this study. This study used qualitative descriptive technique as the data analysis technique. The results of this study indicated a questionnaire design. It was the indicators of instrument development design for metacognitive determination in calculus problem solving. It had the percentage of effectiveness standards classified as good and very good criteria based on the five-scale categorization.

1. Introduction

A person's knowledge grows based on affirmations received from the surrounding environment. Affirmations received continuously will raise much new questions in a person. This is what encourages a person to do a novelty for certain objects through a higher thought process. This theory was sparked by some authors such as Piaget, Dubinsky and Sfard [1-3]. It is same as with Gray and Tall [4] said, a thought process arising from environmental affirmations will give rise to a concept that can be used for the novelty of an object. Where in the process will require certain symbols as a reminder of the procedure. These symbols can be used to solve problems in real life. Some of these learning symbols are summarized in calculus learning.

The chapters in calculus learning are related to one another. They start from the basic concepts of calculus to higher mental processes. It is important for students to understand them systematically, starting from the basic to the most complicated. If it is not done systematically, it will be difficult for students to solve calculus problems [5]. There were several studies that analyze it in the context of mathematics [6-11]. Some were in the context of physics [12]. There were also those in other contexts [13].

Engineering students require taking calculus courses. It means that there will be students who have a variety of characters in calculus learning. This will imply that it is necessary to develop curriculum design and interpretation to evaluate its effectiveness. It is not uncommon to find only a few students who focus on learning calculus while others are not. So it is necessary to analyze the character possessed by each student so that learning objectives can be achieved according to the applicable curriculum directions [14].

The student character problems in calculus learning are not an obstacle that cannot be solved. It is overcoming the characters diversity can be done by raising their awareness through metacognition process. Apart from cognitive, affective and psychomotor, metacognition also has an important role in the problem-solving process, especially in self-awareness [15-16]. The results of field study [17-18] and laboratory study [19] showed that students who tend to engage in metacognitive activities had a higher level of achievement than others. Brown and Palincsar conducted research related to metacognitive activities in the context of reading, while Van den Boom et al. investigated in the context of web-based learning [20].

The results of research conducted by Yoonhee Jang et al. proved that the balance between metacognitive abilities which students have and their metacognitive practice experiences can lead students to become aware [21]. The awareness which means of it is realizing the importance of the self-monitoring role in solving a problem. The existence of this balance will make students able to overcome their difficulties when carrying out metacognitive activities in various situations. The fluid intelligence will be formed with the development of students' metacognitive abilities. It is what trains students' abstract reasoning when solving a problem. In other words, it is one step for the improvement of cognitive abilities as well [22], be it in a social, economic and health context [23], in the context of concentration and remembrance [24-25], and in the context of the skills and knowledge application [26-32].

In calculus learning related to metacognitive problems in problem solving, it is very important to take metacognitive measurements so that the direction of learning can be predicted properly. This metacognitive measurement can be done by using an instrument for metacognitive determination in calculus problem solving is the form of a questionnaire. the strategy plays an important role in the development of an instrument. The strategy that often plays a role in it is a constructive strategy [33] and one that avoided is the elimination strategy [34-36]. Apart from strategy, something that also has an important role in instrument development is Likert [37-39]. Referring to the problems that occur in the field and the research results related to calculus learning and metacognitive questionnaires, the researchers were interested in conducting research related to the design of the development of metacognitive determination tools in calculus problem solving.

2. Methods

The research methodology can be used as a general sketch form to a reference for procedures in conducting research [40]. This study used a development approach with the research and development method with Borg & Gall model that focuses on the design stage [41]. This research methodology discussed instrument development design for metacognitive determination in calculus problem solving. It is designed in the form of an early indicator forming a metacognitive questionnaire in calculus problems solving.

The subjects involved in this study were two psychologist experts and three education experts. The object of this research was a metacognitive questionnaire design in calculus problem solving. Observation, interviews, literature study and documentation were data collection techniques used in this study. This research was conducted at the Institut Teknologi dan Bisnis STIKOM Bali in the calculus class.

Primary data in this study was in the form of quantitative data from respondents which used as a reference for decision making on the effectiveness standard percentage of metacognitive questionnaire designs in calculus problem solving. Where in retrieval using observation techniques and literature study. Secondary data were obtained using interview and documentation techniques. It was qualitative data which tends to be able to support percentage figures in primary data.

Descriptive quantitative analysis was the data analysis technique used. The result of effectiveness standard percentage in this study was obtained by equation (1) [42].

$$\text{Percentage}=\frac{\sum \text{(response x each choice integrity)}}{\text{n x highest integrity}} \text{ x } 100\% \qquad (1)$$

Note:
$\sum$ = sum
n = total number of questionnaires item

The effectiveness standard percentage results of metacognitive questionnaire design in calculus problem solving were then converted into a five scales categorization. The calculated value of the percentage among 90%-100% includes very good criteria with affirmations which do not need revision. The calculated value of the percentage among 80%-89% includes good criteria with affirmations which need a minor revision. The calculated value of the percentage among 65%-79% includes enough criteria with affirmations which need revision. The calculated value of the percentage among 55%-64% includes criteria lacking with affirmations which need revision. The calculated value of the percentage among 0%-54% includes poor criteria with affirmations which need revision.

3. Results and Discussion

Based on the research phase and field data collection, there were four standard metacognitive levels of metacognitive questionnaire design in calculus problems solving. The four levels were Tacit use, Aware use, Strategy use and Reflective use [43]. On each metacognition level there were three metacognitive aspects / criteria adopted from the Awareness of Independent Learning Inventory (AILI). Those were Metacognitive Knowledge, Metacognitive Regulation and Metacognitive Responsiveness [44]. The following were some indicators related to metacognitive questionnaire design standards in calculus problem solving.

3.1. Tacit Use

Tacit Use which means students use thoughts in solving calculus problems without realizing what and why thoughts are used. The indicators used as design standards for the Metacognitive Knowledge aspects were 1) unable to provide an explanation of the understanding obtained after listening to calculus questions; 2) He/she does not realize the form of Calculus problems that had to be worked out systematically; 3) He/she does not pay attention to the importance of calculus problems in life. In the Metacognitive Regulation there were indicators: 1) He/she does not realize that solving Calculus problems can attract interest in learning; 2) He/she does not pay close attention to all the forms of understanding obtained about calculus problems; 3) He/she does not realize the purpose of learning in solving Calculus problems. In Metacognitive Responsiveness there were indicators: 1) solves Calculus problems without self-checking the systematicity of answers; 2) ignoring criticism and suggestions for the understanding obtained about calculus problems; 3) ignoring the added insights gained in calculus learning

3.2. Aware *use*

Aware use, it has meaning that students use their idea in solving problems. The indicators used as design standards for the Metacognitive Knowledge aspects were 1) realizing the need for conscious efforts in understanding Calculus problems; 2) it is able to formulate a form of understanding calculus problems; 3) realizing of mistakes when understanding the problem. In the Metacognitive Regulation there were indicators: 1) be aware of the many things that can be learned from people in a study group; 2) know about the uselessness of a task; 3) aware of the relationship between tasks and personal goals. In Metacognitive Responsiveness there were indicators: 1) Realizing the importance of working together in a study group to solve calculus problems; 2) realize the suitability of the cooperation method in a task; 3) realize that a calculus problem can provide valuable lessons.

3.3. Strategy *use*

Strategy use, which means students direct their thinking processes by realizing specific strategies that increase the accuracy of their thinking. The indicators used as design standards for the Metacognitive Knowledge aspects were 1) pay attention to how well the self-learned information; 2) He/she has a way of solving unproductive cooperation in study groups; 3) He/she has a strategy about what needs to be done to study thoroughly when starting to solve a calculus problem.

In the Metacognitive Regulation there were indicators: 1) realize that solving a calculus problem will attract interest in learning; 2) know what can be learned from colleagues in solving calculus problems collaboratively; 3) have a clear idea of what you want to learn from solving a calculus problem.

In Metacognitive Responsiveness there were indicators: 1) recognize the importance of personal feedback about learning goals; 2) know how much effort it takes to solve a calculus problem; 3) using strategies to communicate with learning group members about the benefits of working together in solving calculus problems.

3.4. Reflective *use*
Reflective use, which means students reflect on their thoughts before and after or even in the middle of the thought process, by considering the acquisition and how to improve it. The indicators used as design standards for the Metacognitive Knowledge aspects were 1) assess the usefulness of calculus problem solving that have been done, it towards personality; 2) cross check with group members about calculus problem solving that has been done; 3) overcomes the questionable personal involvement in performing calculus problem solving.

In the Metacognitive Regulation there were indicators: 1) assess how much can be learned from group members by working together to solve calculus problems; 2) evaluate the differences in understanding that sometimes occur when working together in calculus problem solving; 3) assess self-interest in calculus problem solving.

In Metacognitive Responsiveness there were indicators: 1) find out the errors contained in problem solving that carried out; 2) evaluate the systematics of calculus problem solving that has been done; 3) trying to find deeper reasons when finding information that is difficult to understand.

Based on the standard indicators of metacognitive questionnaire design in calculus problem solving that had been described above, the result was the percentage of the effectiveness standard. The complete results of the effectiveness standards percentage can be shown in Table 1.

The effectiveness standard percentage results of metacognitive questionnaire indicators in calculus solving problems showed the good and very good criteria. The criteria that considered good were several indicators that had effectiveness standard percentage of 85%, 86%, 87% and 88%. It showed that the indicators which had those effectiveness standard percentages in their affirmation require minor revisions. Criteria that considered very goods were several indicators which had effectiveness standard percentage result of 90%. It showed that the indicators which had effectiveness standard percentage in their affirmation did not require revision.

4. Conclusion
Instrument development design for metacognitive determination in calculus problem solving in this study was able to show several indicators which had good and very good criteria. Where the indicators obtained in this study were arranged systematically according to the metacognitive level in Calculus Problem Solving. It also arranged according Metacognitive Aspects/Criteria which were adopted from the AILI concept. It is expected to be able to conduct field evaluations and make decisions on several metacognitive questionnaire indicators in calculus problem solving after doing a minor revision.

Table 1. Effectiveness standard percentage of metacognitive questionnaire indicators in solving. Calculus Problems

Metacognition Level in Calculus Problem Solving	Metacognitive Aspects / Criteria	Indicator	Effectiveness Standards Percentage (%)
Tacit use	Metacognitive Knowledge	1	88
		2	90
		3	88
	Metacognitive Regulation	1	90
		2	85
		3	85
	Metacognitive Responsiveness	1	87
		2	87
		3	88
Aware use	Metacognitive Knowledge	1	88
		2	88
		3	88
	Metacognitive Regulation	1	90
		2	87
		3	86
	Metacognitive Responsiveness	1	86
		2	86
		3	87
Strategi use	Metacognitive Knowledge	1	87
		2	88
		3	88
	Metacognitive Regulation	1	88
		2	88
		3	88
	Metacognitive Responsiveness	1	88
		2	88
		3	87
Reflective use	Metacognitive Knowledge	1	86
		2	90
		3	90
	Metacognitive Regulation	1	90
		2	90
		3	88
	Metacognitive Responsiveness	1	87
		2	86
		3	90

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