A comparison of types of knowledge of cognition of pre-service biology teachers

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Received 8 Nov., 2017
Revised 22 Jun., 2018

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Abstract

This research aims to compare three kinds of knowledge of cognition underlying the reflective aspects of metacognition. The three kinds of cognition considered in this research are declarative knowledge, procedural knowledge and conditional knowledge. This exploratory research survey involved 122 pre-service biology teachers during their third semester of training. The instrument used to gather data was the Metacognitive Awareness Inventory (MAI) of Schraw and Denisson (1994), modified by use of a Likert scale. The data gathered were analyzed using one-way analysis of variance (ANOVA) followed by a least significant difference (LSD) test. The results of this research show that the kind of knowledge of cognition of pre-service biology teachers which was most highly developed in the research sample was conditional knowledge, followed by procedural knowledge and declarative knowledge, between which there was no significant difference. This high level of conditional knowledge as compared with the other two knowledge types could result from this type of knowledge being stimulated to a greater extent than the other two types. Based on the results of this research, it is recommended that, in order to stimulate knowledge of cognition, especially conditional knowledge, lecturers in biology education should provide challenging learning environments containing clear problems and tasks, and simultaneously implement a reward system for students.

Keywords: conditional knowledge, declarative knowledge, knowledge of cognition, procedural knowledge

Introduction

Metacognition is one's ability to control cognitive processes; it can be seen as a concept that describes 'cognition about cognition', 'thinking about thinking', or 'knowing about knowing'. Metacognition describe one's knowledge of how to perceive, remember, think, and act on what we know, based on what we have known (Metcalfe & Shimamura, 1994). Metacognition also plays an important role in oral communication, oral persuasion, oral comprehension, reading, writing, receiving language, attention, memory, problem solving, social cognition, and various types of self-control (Flavell, 1979). In general, it can be said that the cognitive processes and outputs of an individual or their self-knowledge reveal their metacognition (Cikrikci

& Odaci, 2016). The important role of metacognition can be understood from the constructs or components of metacognition itself.

Metacognition consists of two main components, namely knowledge of cognition and regulation of cognition (Byun, Lee, & Cerreto, 2013; Dejonckheere, Van de Keere, Tallir, & Vervaet, 2013; Ma & Baranovich, 2015). Knowledge of cognition is the knowledge a person has about when and how to implement a strategy appropriately (Javid, Alavi, & Pour, 2013), and consists of three aspects: declarative knowledge, procedural knowledge, and conditional knowledge (Schraw, Crippen, & Hartley, 2006; Sperling, Howard, Miller, & Murphy, 2002). Meanwhile, regulation of cognition comprises five skills: planning, information management strategy, comprehension monitoring, debugging strategy, and evaluation (Schraw et al., 2006; Schraw & Dennison, 1994a). The measurement of knowledge of cognition and regulation of cognition have been developed into the chief measuring tool of metacognition, known as the Metacognitive Awareness Inventory (MAI), developed by Schraw & Dennison, (1994); this tool has been widely used in various parts of the world (Corebima, 2009; Jacobse & Harskamp, 2012). The reliability of this instrument has also been extensively tested, such as in the study conducted by Sperling et al. (2002).

Knowledge of cognition, often referred to as the knowledge of metacognition (Krathwohl, 2002), is one of the components that plays an important role in monitoring the productivity of metacognition. The monitoring of cognition productivity, supported by knowledge of metacognition, is also influenced by the actions and reactions of the phenomena of the metacognitive experience, purpose, or task to be achieved, and the strategies adopted to face and solve problems (Flavell, 1979). Knowledge of cognition is what someone knows about their cognition in general (Schraw, 1998) and the possibility of implementing strategies (Garrison, 2003). Knowledge of cognition also determines the ability to become an independent learner (Duffy, Miller, Parsons, & Meloth, 2009). Knowledge of cognition includes knowledge used in approaching the questions ‘what’, ‘how’, ‘when’, and ‘why’ (Ma & Baranovich, 2015). Knowledge of cognition contains at least three aspects of cognitive awareness: declarative knowledge, procedural knowledge, and conditional knowledge (Schraw, 1998).

Declarative knowledge is knowledge 'about' something (Azevedo & Aleven, 2013), that is, the knowledge of what one knows, and the knowledge of how to learn and what factors influence the learning process (Young & Fry, 2012). Declarative knowledge is concerned with the insights of a person about their processing ability and the factors that affect their performance (Backer, Keer, & Valcke, 2011). This knowledge is immediately detected, for example, when a person is aware when reading of the gap between their understanding and the demands of the text (Dabarera, Renandya, & Zhang, 2014).

Procedural knowledge is the knowledge about successful methods used to achieve specific learning goals and an awareness of how specific cognitive skills are applied in learning (Backer et al., 2011). Knowledge about methods that can be used to achieve success will provide security for a person in facing various problems. The confidence to resolve the problems related to learning activities grows with the ability to apply cognitive skills. Procedural knowledge is the knowledge about the strategies which can be used to improve performance (Yore & Treagust, 2006). Procedural knowledge can be considered as an admission mechanism for abstract concepts. The direct teaching of procedural knowledge helps individuals to approach new scientific knowledge (Zoupidis, Pnevmatikos, Spyrtou, & Kariotoglou, 2016).

Conditional knowledge is related to knowledge of external conditions, so that the use and effectiveness of certain strategies can be appropriate to those conditions (Backer et al., 2011). Conditional knowledge is an understanding of when and how to use something we already know, for example, using different strategies in different situations (Larkin, 2009). Yore and Treagust (2006) state that conditional knowledge is the awareness of how, when, and where to use certain strategies. Conditional knowledge emphasizes knowledge which connects facts, so that it is a form of inductive reasoning, that is, making a decision based on facts collected together (Kiesewetter et al., 2016).

According to Schraw & Dennison (1994b), the three types of knowledge of cognition are related to each other and are able to predict each other. Hence, these three types of knowledge of cognition can provide insights into each other. If one type of knowledge of cognition is at a high level, the others are also, and vice versa, and so declarative knowledge, for example, can help to develop strong procedural knowledge (Azevedo & Aleven, 2013). The use and selection of appropriate strategies reflect conditional knowledge, which is the culmination of cognition.

The measurement and pre-assessment of metacognitive aspects are important because such information can help students by being used to provide the opportunity to improve their metacognition (Tanner, 2012). Metacognitive knowledge is significantly correlated with cognitive retention, and Palennari (2016) states that this has a greater contribution to learning outcomes than learning motivation (Bahri & Corebima, 2015). Educators who understand students' metacognitive knowledge levels are expected to be better in optimizing the learning process that will be implemented in order to achieve predetermined objectives.

Based on the elaboration above, it can be seen that these three types of knowledge of cognition are interrelated, so that a hypothesis can be proposed that there is no difference in the levels of the various aspects of knowledge of cognition within an individual. Therefore, this research aims to illustrate that there is no difference in the three types of knowledge of cognition in pre-service biology teachers.

Methodology of Research

General background to the research

This research took place in the third semester of 2015 in the Biology Education Department, Teacher Training and Education Faculty, Muhammadiyah University of Surakarta. It took the form of an explorative survey that sought to provide a true description of the participants' thinking in light of selected variables, in this case, aspects of metacognitive knowledge. Without intervention, participants' metacognitive knowledge was measured using the MAI. The results for the three metacognitive knowledge types were then compared, analyzed statistically, and reviewed in light of a review of relevant literature. The description of students' metacognitive knowledge is useful for lecturers in assisting them to optimally implement the learning process to maximize achievement of learning objectives.

Research sample

The participants involved in this research were pre-service biology teachers in the third semester of their training. The participants were divided between four classes, and numbered 122 students in total. The students were divided between classes by the Biology Education Study Programme based on administrative considerations, not on considerations of academic achievement. All the participants completed the metacognition measurement instruments. The research and sampling was granted permission by the Post Graduate Programme of the State University of Malang to the Biology Education Department of the Teacher Training and Education Faculty of Muhammadiyah University of Surakarta.

Instrument and procedures

Metacognition was measured using the MAI, which is a tool developed some time ago (Schraw & Dennison, 1994a) that has since been used extensively worldwide (Corebima, 2009; Jacobse & Harskamp, 2012). The reliability of this instrument has also been extensively tested, such as in the study carried out by Sperling et al. (2002), and this suggests that it is appropriate for collecting data regarding metacognition.

The MAI consists of 52 question items, 17 addressing knowledge of cognition and 35 addressing the regulation of cognition. The knowledge of cognition questions address eight declarative knowledge items, four procedural knowledge items, and five conditional knowledge items. The regulation of cognition questions address seven planning items, 10 items relating to information management strategies, seven comprehension monitoring items, five items relating to debugging strategy, and six evaluation items (Schraw & Dennison, 1994a).

The MAI used was modified by applying a Likert scale, The use of which is intended to determine the level or gradation of participants' responses. Furthermore, the scores collected for each type of knowledge were converted into a scale of 100, using the formula

$$\text{Cognitive Score} = \frac{\text{score}}{\text{max score}} \times 100$$

Data analysis

The scores obtained for each type of knowledge were then analyzed by using one-way analysis of variance (ANOVA). As assumption tests, a normality test and a homogeneity test were performed before hypothesis testing. The normality test used was the Shapiro-Wilk test and the homogeneity test used was Levene's test (Hidayat, 2014). The results of the ANOVA test were followed up by a post hoc LSDtest if needed. All the statistical tests were performed using SPSS 22 for Windows.

Results of Research

Metacognitive knowledge (declarative knowledge, procedural knowledge, and conditional knowledge) present differences in their means and standard deviations. The data description for declarative knowledge (DK), procedural knowledge (PK), and conditional knowledge (CK) are shown in Table I.

Table I. Description of the values for knowledge of cognition

Knowledge of cognition - type	N	Mean	Std. deviation	Std. error	Minimum	Maximum
DK	122	72.85	8.93223	.80869	50.00	95.00
PK	122	73.98	10.92685	.98927	45.00	100.00
CK	122	76.72	9.14191	.82767	56.00	100.00
Total	366	74.52	9.19461	.51318	45.00	100.00

The summary of the results of the normality test of the distribution of the data related to the three types of knowledge is presented in Table II.

Table II. Summary of normality test results

Knowledge	Shapiro-Wilk test		
	Statistic	df	p
DK	.988	122	.359
PK	.980	122	.061
CK	.979	122	.054

Furthermore, the summary of the results of the homogeneity test using Levene's test are presented in Table III.

Table III. Summary of the results of the statistics test

Levene statistic	df1	df2	p
2.830	2	363	.060

The two assumption-test results show that hypothesis testing can be performed. The summary of the ANOVA test is presented in Table IV.

Table IV. Summary of the ANOVA test

	Sum of squares	df	Mean square	F	p
Between groups	968.272	2	484.136	5.137	.006
Within groups	34213.395	363	94.252		
Total	35181.667	365			

The results of the ANOVA test presented in Table IV show that there are significant differences between the three types of metacognitive knowledge, namely DK, PK, and CK. To determine which knowledge of cognition is the most different, a post hoc analysis was performed. The summary of the post hoc test using LSD is presented in Table V.

Table V. Summary of LSD test results on the cognitive knowledge of biology students

Knowledge type	Average	LSD notation
DK	72.8484	a
PK	73.9754	a
CK	76.7213	b

Table V shows that there was no significant difference between DK and PK. The most striking difference was for CK, which had the highest average among the knowledge types, and significantly differed from DK and PK. It is the case that the three types of knowledge are interrelated with one another; declarative knowledge supports procedural knowledge and conditional knowledge.

Discussion

Knowledge of cognition is the ability of an individual to assess their own cognition (McMahon, Henderson, Newell, Jaime, & Mundy, 2016). Knowledge of cognition is closely related to the regulation of metacognition (Tock & Moxley, 2016). Human knowledge about cognition reflects what is happening in the brain, and this is deeply shaped by formal education and literacy and so cannot be generalized to all humans (Demoulin & Kolinsky, 2015). Human knowledge of cognition is limited by the capacity of human cognition as seen from a wider context, including factors such as evolution, social relationships, and language (Werner, 2016). Metacognitive knowledge refers to acquired knowledge about cognitive processes, and this is knowledge that can be used to control cognitive processes (Aberšek, Dolenc, & Kovačič, 2015).

In general, cognitive knowledge comprises strategic knowledge, that is, knowledge of cognitive tasks. This includes the context of knowledge and the best conditions for it, as well as knowledge of oneself (Airiasian et al., 2001; Krathwohl, 2002). Cognitive knowledge is one component in a metacognitive system, the metacognitive system being the 'engine of learning' in an individual (Marzano, 1998). The effectiveness and performance of a person in learning are determined by the performance of this learning engine. Cognitive knowledge is about what one knows about oneself or about ones cognition in general. Cognitive knowledge is associated with the regulation of cognition (Schraw, 1998).

Cognitive knowledge and cognitive regulation have an effect on mental performance. For example, low efficacy and self-motivation may be due to a lack of knowledge about the strategy required (Ma & Baranovich, 2015), which is a part of procedural knowledge. Procedural knowledge is knowledge about a procedure (Rittle-Johnson, Schneider, & Star, 2015). On the other hand, declarative knowledge and procedural knowledge are mutually supportive. Thus, a person who already has declarative knowledge about a particular strategy and has used it previously tends to be more critical in using that strategy (Veenman, 2011).

Declarative knowledge is the simplest cognition, as it only requires the processing of data about existing information (Michalsky, 2012). Declarative knowledge is the understanding of oneself as a learner and the factors that affect learning performance, for example, knowing ones own weaknesses in recalling facts. The weaknesses which are understood by a person about themselves demand the application of procedural knowledge to overcome them, for example, by implementing a note-taking strategy, storing important information, summarizing, training, and so forth. Furthermore, a variety of strategies to overcome this weakness will be selected and there will be specific reasons why and when these selections are made. This is known as conditional knowledge.

The development of the knowledge of cognition is also affected by age. Adults generally have higher levels of cognition than children and adolescents (Schraw et al., 2006). In general, each type of knowledge will increase simultaneously (Cho & Cho, 2013). This means that if a person has a high level of declarative knowledge, their procedural knowledge and conditional knowledge levels will also be high; there is not a significant difference among the three. In a certain situation, such as when a person faces a reading passage, a person will be encouraged to use their declarative knowledge when they recognize a gap between their understanding and the demands of the text. This condition triggers the use of procedural knowledge by looking at the condition faced, and this is the embodiment of conditional knowledge (Dabarera et al., 2014).

Cognitive knowledge organization is helped by monitoring along a more general dimension of effortful control (Pillow & Pearson, 2014). Knowledge of cognition not only plays a role in learning activities but also in children's ability to make financial management decisions (Lee & Koh, 2016). The implementation of forms of control and regulation of cognition are greatly influenced by conditional knowledge. The knowledge and mental processes already possessed will be under the final control of conditional knowledge. This situation allows the conditional knowledge of a person to be at a higher level than their declarative and procedural knowledge. Conditional knowledge also develops more quickly than the other types of knowledge.

High levels of conditional knowledge compared with the other types of knowledge are commonly found, for example, in the implementation of learning models such as modified project-based learning (Gassner, 2009). Conditional knowledge is also more stimulated than the other knowledge types. Declarative knowledge is stimulated by 'what' questions and procedural knowledge is stimulated by 'how' questions, while conditional knowledge is stimulated by both 'when' and 'why' questions (Mohtadi, Hajami, & Allali, 2014). In fact, in addition to 'when' and 'why', conditional knowledge is also stimulated by the question, 'where' (Hacker, Dunlosky, & Graesser, 2009). Considerations of all conditional aspects of learning are an important factor in improving the general metacognition of a person (Conner, 2007). Thus a greater amount of stimulation becomes the factor leading to the development of a higher level of conditional knowledge than of the other knowledge types. Individuals with a high level of conditional knowledge are more able to assess the demands of certain learning situations, and, in turn, to choose the most appropriate strategies for them (Schraw et al., 2006).

That conditional knowledge level is higher than cognitive knowledge also suggests that conditional knowledge is the key to the functioning of the other forms of knowledge. Conditional knowledge is a form of knowledge that allows declarative knowledge to become functional in order to derive benefit from cognition skills or procedures (Cikrikci & Odaci, 2016). Conditional knowledge enables a person to adapt in accordance to the changing situation of a learning task (Schraw, 1998). Conditional knowledge becomes the facilitator of the functioning of knowledge which is related to the question, 'what'. This means that conditional knowledge is related to the knowledge that is able to correctly identify when a strategy or a skill is relevant to the tasks or problems faced.

A new problem or challenge faced in learning requires that the appropriate skills and strategies are used. Based on the previously discussed points, a person will use their chosen strategies to overcome problems. Such conditions will stimulate the development of conditional knowledge (Hsu, Iannone, She, Hadwin, & Yore, 2016). The demands of the conditions encountered lead a person to discover the 'when', 'where', and 'under what conditions' of the situation at hand (Hulsbos, Evers, & Kessels, 2016). Adaptation to a new situation in college compared to the learning situation in senior high school, for example, has a role in stimulating the development of conditional knowledge. In this example, the new situation may be, for instance, the existence of a wide variety of learning resources, friends with diverse socio-cultural backgrounds, diverse characteristics of the course and lecturers, and so forth (Stadtler, Scharrer, Macedo-Rouet, Rouet, & Bromme, 2016). The diversity of the new situation faced also requires the development of the knowledge of creativity, divergent thinking, and understanding of the task, strategy, and even knowledge of oneself, which are all aspects of conditional knowledge (van de Kamp, Admiraal, & Rijlaarsdam, 2016).

Conclusions and Recommendation

This research concludes that there is a significant difference between the three kinds of cognitive knowledge, namely declarative knowledge, procedural knowledge, and conditional knowledge, in biology education students. Declarative knowledge and procedural knowledge did not display a significant difference. This suggests that under certain conditions, declarative knowledge and procedural knowledge are at the same level of performance. Meanwhile, conditional knowledge revealed the highest average level and showed a significant difference from the other two knowledge types.

Based on the results of this research, it is recommended that the learning activities used in higher education, particularly those conducted by lecturers in biology education, need to optimize learning and stimulate cognitive knowledge. Learning which is able to increase cognitive knowledge is that which challenges students, in which they are faced with a problem and a task to be completed. In such activities, students become accustomed to not only accepting learning material, but also have their thinking ability developed through problem-solving tasks. The tasks given to students need to be clear, and to include the criteria for success in completing them. In addition, these challenging situations must also be able to motivate students because of a promised reward system. The challenge of the problem and the hope of achieving a reward will continuously enrich students' knowledge of the skills and strategies they possess to successful address new situations. Such learning stimulates the development of students' knowledge of cognition, especially their conditional knowledge.

Acknowledgements

This research was supported by a Grant of Dissertation Research and New Doctorate of Sebelas Maret University, Surakarta Indonesia.

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