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Metacognitive and Conceptual Understanding of Pteridophytes: Development and Validity Testing of an integrated Assessment Tool

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Abstract

The use of question instrument in determining achievement of students' study goal can be referred from the score achieved by the students in solving contextual questions with solution or solving strategy in high level of thinking. The research aims to get integrated assessment tools of conceptual understanding of Pteridophyta and metacognitive skill that is validated and can be used in learning activity. The research is conducted in July 2018 – November 2019 at Universitas Negeri Jakarta, course of Botany Cryptogamae, sub-course Pteridophytes. This is a Research and Development study using 4D method (Define, Design, Develop, and Disseminate). However, the research will be conducted up to the develop phase only. The result shows that integrated assessment tool on conceptual understanding of Pteridophytes and students' metacognitive skill is proper to be used, with expert validation result shows 78.13 on criteria for concept understanding, and 79.17 for students' metacognitive skill. Result of instrument validation shows more than 0.396, means it is valid, and reliability more than 0.6.

1. INTRODUCTION

Biology is a branch of natural sciences that provides various learning experiences to conceptual understanding as well as how to manage learning activities (Wiljeng, 2010; Corebima, 2016, Ristanto, et al., 2018). One branch of biology that is categorized as the basic learning is Botany of Cryptogamae sub-course Pteridophytes. The problem of conceptual understanding of Pteridophyte content includes a subject on plant classification and taxonomy where identification has a high complexity of content in distinguishing one species to another (Suraida, 2012; Hanif, 2016).

The learning objectives of biology, both in high school or in college is to gain skills needed in the 21st century such as critical thinking, problem solving, communication, collaboration, creative and innovative thinking. Hence, it refers to the learning accomplishment or the achievement of student's study goal (Corebima, 2016; Ristanto, et al., 2018; Djamahar, et al., 2018). The learning objectives of biology include: (a) to develop experience of proposing and testing hypothesis through experiments, as well as communicating the result orally and literally; (b) to develop analytical, inductive, and deductive thinking ability using biological concepts and principals; (c) to develop mastery on interrelated biological concepts and principals (BSNP, 2006).

According to those objectives, there are important aspects of conceptual understanding in learning activities, including providing or adding information to enrich learning material resources (Lukitasari et al., 2014; Sartono et al., 2018), making it easier to construct or connect between learned concepts and the basic concept that has been previously learnt (Afrilianto, 2012). One is considered as having a conceptual understanding if students can define concept, identify and giving examples or non-examples of the concept, as well as able to connect between one subject or idea and another (Kesumawati, 2008; Laying, 2013; Retno et al., 2018). On another aspect, metacognitive skill is needed in managing someone's learning activity (Howard 2004; Dedic, 2014; Ramdiah et al., 2014; Darmawan et al., 2018; Pratama, 2018), such as

future learning strategy planning, observing the ongoing learning activity, as well as evaluating cognitive activities or identifying weaknesses, mistakes, or advantages after learning the subject, so that it will empower thinking skill (Basith, 2012; Pratama, 2018; Djamahar et al., 2018).

Metacognitive skills and conceptual understanding will influence active control of cognitive processes in learning and everyday life (Mariati, 2012; Sarah et al., 2016) including activities for understanding, communication, and controlling the learning environment (Howard, 2004; Schrow et al., 2006) which directs higher orther thinking skills in accordance with Biological characteristics that have the potential to empower thinking skills (Basith, 2012). In Pteridophytes, the problem of conceptual understanding that often occurs is among others the lack of understanding of foreign terms (Suraida, 2012), abstract concepts on the subject of classification and taxonomy (Hanif, 2012). On metacognitive skills such as the unsystematic answers in prioritizing answers that are answered first, and not evaluating the accuracy and correctness of answers that have been answered and the demands of the subject matter very much (Rohman, 2016; Palennari, 2016).

Formally, the achievement of student's study goal can be seen through various aspects. One of them is the cognitive score. The use of question instrument in determining the achievement of student's study goal can be seen from the score gained by the students in accomplishing contextual questions with solution or solving strategy in high level of thinking (Rahayu et al., 2008; Wati et al., 2016). However, most of the questions are delivered in form of multiple choices, fill-in, or essay that tend to require remembering and memorizing instead of understanding or developing the basic concept that has been learned better (Susangko, 2010; Marwiyah et al., 2015). On the other side, learning objective requirements have led to activities of analyzing, evaluating, and discovering or inventing, which are expressed in critical thinking (Villafane, et al., 2011). As for achieving that aspect, an understanding on basic concept is needed, as well as students' initiative in finding literatures or managing their study, so that they are skillful in constructing knowledge and their understanding on subject being studied or discussed (Mariati, 2012; Ristanto et al., 2018).

Tendency to solve low-level thinking problems can reduce the level of students' way of thinking. The question given should be able to direct thinking activities, where they are obliged to think more instead of just remembering the standard procedures in solving particular problems (Cooper et al., 2009; Amir et al., 2018). Hence, students are required to not directly answer the question. Instead, there is a thinking activity that directs them to construct subject they have learned, so that they are able to plan before obtained the answer, as well as train the construct thinking pattern based on the learning objective that has been learned (Rahayu et al., 2008; Vandergrift et al., 2006).

One of the question instruments that can develop students' thinking ability is the essay. The advantage of essay is it gives freedom to the students to use their thinking abilities. Thus, their answers vary depending on their own thinking ability and creativity (Cooper et al., 2009). However, it has a weak point, especially for the teacher, since it takes much time to review and analyze their answers (Zubaidah et al, 2015). Thus, it may not cover some indicators of assessment (Susangko, 2010). One applicable strategy is to integrate several variables to be assessed, such as the conceptual understanding variable with metacognitive skill (Prayitno, 2015). Instrument integration process has advantages, including it simplifies the questions to be used so that it may reduce the number of questions, yet it will be more effective and critical by combining several indicators inter-variables.

According to the explanation above, an integrated question assessment is needed. The one that can include some variable aspects with special subject, such as the conceptual understanding of Pteridophytes and students' metacognitive skill, aiming at familiarizing the students to analyze and synthesize prior to answering questions based on constructive activities in accordance to the learning objectives to be achieved.

2. RESEARCH METHODS

The research was categorized into a Research and Development, using a method adapted from Thiagarajan et al., (1974) called the 4D (Define, Design, Develop, and Disseminate). However, the research was conducted up to the develop phase only. Research population was 33 students who had taken the Botany of Cryptogamae course in Biology Education Department, Faculty of Mathematics and Natural Sciences, Universitas Negeri Jakarta in 2018/2019 academic year. Validity analysis of question for empirical validation used SPSS 16.

a. **Define:** the define phase consisted of front end, student's analysis, assignment analysis, as well as content concept analysis. The front-end analysis was conducted by interviewing the lecturer. The student analysis was conducted by giving questions in form of matching and essay. The assignment analysis was conducted by analyzing the result of front end and student's analysis. The content concept analysis was conducted by analyzing taught materials from various sources concerning conceptual understanding and metacognitive skill. Material concept analysis is conducted by analyzing material that will be used to develop integrated question assessment of conceptual understanding and metacognitive skill.

b. Design: it included phases of: creating outline, determining indicators to be used, as well as developing integrated instrument of conceptual understanding of Botany of Cryptogamae and students' metacognitive skill based on HOTs (Higher Order Thinking skill) that would be adjusted in accordance with Semester Learning Plan (*Rancangan Pembelajaran Semester*, RPS) as well as determination of scoring criteria.

c. Develop: it included experts scoring and empirical validation. The sequences of development are as follows.

1) Expert scoring; referred to education experts with the qualification of Doctor in Biology Education, especially in botany field, as well as having conceptual understanding and metacognitive skill. The validation basis was the subject on Botany of Cryptogamae, especially Pteridophytes, RPS, outline of conceptual understanding and metacognitive skill (Prototype I).
2) Empirical Validation: referred to validation result of expert scoring, both the expert of subject and the expert of conceptual understanding and metacognitive skill. The scoring of conceptual understanding and metacognitive skill integrated question used *person product moment* (PPM) using SPSS 16 for analysis.

3. RESULTS AND DISCUSSION

Results from each phase of conceptual understanding of Pteridophytes and students' metacognitive skill of integrated assessment tool development will be explained as follows.

1. *Define*

The stages to determine the development of conceptual understanding of Pteridophytes and students' metacognitive skill integrated assessment tool will be explained as follows.

a. Front-end analysis

Student analysis was conducted through survey with respondents from lecturer and students taking the Botany class. Survey was conducted in July 2018. Question component for lecturer interview were specialized on the ongoing learning activity that covered learning model that is frequently used, difficulties faced by the students during the learning activities, as well as the standard of exam question commonly used. Interview results are presented in Table 1.

Table 1. Results of interview with the lecturer of Botany.

No	Interview Component	Result
1.	Learning Model	The implementation of learning focuses on lectures, tasks, discussions, presentation, questioning and answering.
2.	Students' difficulties/ weaknesses	Students were having difficulties to basic conceptual understanding of learning so it was difficult to direct them to a constructive learning. In addition, they tended to wait the lecturer's order, making them becoming less initiative to find literature sources related to the course materials.
3.	Test questions standard	Tended towards the HOTs (Higher Order Thinking skills), students were not familiar to answer questions in description format.

b. Student Analysis

Based on the result of the interview with the lecturer, it could be concluded that conceptual understanding and metacognitive skill related to the learning independence was still low, this is seen from student responses, learning processes and learning outcomes obtained. Thus, a direct survey to the students was then conducted by giving several question components on conceptual understanding and metacognitive skill. The questions were in form of matching and essay assessment on the sub-subject of Eudicot from the Botany course. It consisted of 20 questions with 23 answers, and one essay with two descriptions. The questions were pre-validated by the expert lecturers and adjusted in accordance with indicators of both aspects. The results presented in Table 2.

According to the result of total average for each indicator, conceptual understanding obtained 63.07, as for metacognitive skill was 50.15, and 56.61 for both aspects combined. If converted to the academic score in Universitas Negeri Jakarta, those average was at the range of C- (Table 2). On conceptual understanding assessment, questions which were the representation of each indicators, presented in matching format, and only few of them were in essay format. On metacognitive skill assessment, all questions were presented in essay format.

c. Assignment analysis

According to the front-end and student's analysis, the result of assignment analysis in the research can be concluded that it required efforts to improve conceptual understanding and metacognitive skill by familiarizing exam in form of valid, practical, and effective essay, yet still in accordance with students' cognitive level.

d. Content concept analysis

The analysis result obtained based on competency and basic competency standards. The competency standard of Botany of Cryptogamae, especially Pteridophyte for Biology Education, Faculty of Mathematics and Natural Sciences in Universitas Negeri Jakarta referred for the research was Pteridophytes with nine sub-subjects. Pteridophytes subject derived from old and new classification.

2. *Design*

a. Stage of outline making & determining indicators to be used

Grids of conceptual understanding of Pteridophytes and metacognitive skill integrated questions are presented in Appendix 1.

b. Development of integrated instrument

Development of conceptual understanding of Pteridophytes and student's metacognitive skill integrated questions will be presented in Appendix 2.

Table 2. Average of Students' Answer According To the Indicators of Botany Conceptual Understanding and Metacognitive Skill

Variable	Indicator	Average	Total Average	Notes	Percentage*	
					P	NP
Conceptual understanding of Pteridophytes	Re-state the learned concept	13.3	63.07	NP	41%	59%
	Classify objects according to particular characteristics	13.3				
	Provide examples and non-examples of the concept	4.9				
	Present the concept in various forms of representation	13.3				
	Develop a 'need' or 'adequate' requirement of a concept	13.5				
	Apply the concept in encountered problems	7.6				
Metacognitive skill	Planning	26.6	50.15	NP		
	Monitoring	13.3				
	Evaluation	10.0				
	Total Average	**56.61**				

Note: P (passed); NP (not passed); Scoring criteria of UNJ: not passed (< 61); C+ between 61; minimum passing criteria for undergraduate students is B- ; *All students.

3. *Develop*

a. Expert scoring

Validation process referred to the education experts with the qualification of Doctor of Biology Education, especially in the Botany field, as well as the conceptual understanding of Pteridophytes and students' metacognitive skill. Validation process used appropriateness scoring of conceptual understanding of Pteridophytes and students' metacognitive skill that referred to the RPS, grids of conceptual understanding and metacognitive skill in form of Prototype I. On the validation process, validators provide suggestions concerning the compatibility of basic competency, indicators, working instructions, as well as estimated time. Whereas the scoring criteria for expert scoring referred to Widodo (2007). Expert validation testing related to the material and aspects to be measured, will be converted to numbers according to predetermined criteria. The entire assessment component such as work instructions, duration of time used, language suitability, and accuracy of the material will be corrected in the form of numbers, with intervals of 1 to 100. Furthermore, with the average that has been obtained can determine criteria approprite or not (Arikunto, 2010).

Table 3. Summary of Expert Validator Scoring for Conceptual Understanding of Pteridophytes

Component	Validator	Percentage of appropriateness (%)	Total average	Conclusion
Conceptual understanding of Pteridophytes	Validator I	81.25	78.13	Appropriate
	Validator II	75.00		
Student metacognitive skill	Validator I	83.33	79.17	Appropriate
	Validator II	75.00		

According to Table 3, it can be concluded that conceptual understanding of Pteridophytes and metacognitive skill integrated instrument was on 'Appropriate' category. Thus it can be subject to validation assessment to empirical study.

b. Result of empirical and reliability validation

Summary result of the proper assessment of conceptual understanding of Pteridophytes and metacognitive skill integrated instrument in the empirical validation assessment will be summarized in Table 4. The assessment tools conducted to 33 respondents of Biology Education Department, Universitas Negeri Jakarta. Respondens were active students who had taken Botany of Cryptogamae course in the 3rd semester (109).

Empirical validation is done to find out the instrument is valid or not (Sugiyono, 2013), and reliability is done to find out the sharpness or accuracy of the items used, so that if the calculated value is greater than the table value, then the instrument can be said to be valid or can be used (Arikunto, 2010).

Table 4. Result of Conceptual Understanding of Pteridophytes and Metacognitive Skill Integrated Instrument Empirical Validation

No.Item	r_{count}	r_{table}	Remarks
1	0.398	0.396	Valid
2	0.462	0.396	Valid
3	0.613	0.396	Valid
4	0.476	0.396	Valid
5	0.396	0.396	Valid
6	0.427	0.396	Valid
7	0.573	0.396	Valid
8	0.704	0.396	Valid
9	0.577	0.396	Valid
10	0.567	0.396	Valid
11	0.527	0.396	Valid
12	0.502	0.396	Valid

Note: Assessment using *Pearson product moment* with criteria: Valid, if $r_{count} > r_{table}$; Not Valid, if $r_{count} < r_{table}$

According to Table 4, the criteria of r_{table} was 0.396 (lowest margin of question item validation), and the result of person product moment correlation analysis, it reveals that every conceptual understanding and metacognitive skill integrated question item exceeded the minimum threshold of 0.396 and considered as valid. The reliability assessment had the lowest range of minimum threshold 0.6, and in overall, the assessment of conceptual understanding and metacognitive skill integrated question was 0.737. Thus, it can be concluded that the questions were having strong or high score stability.

4. CONCLUSIONS AND RECOMMENDATIONS

Based on the research result, the design of conceptual understanding of Pteridophytes and students' metacognitive skill integrated question instrument was considered as appropriate to be applied in the course of Botany of Cryptogamae sub-subject Pteridophytes. This integrated instrument design is expected to be able to assist the lecturer or facilitate them in designing questions more creatively and interesting, so that students' understanding on integrated questions is led to higher level of thinking and not burden them with a large number of essay questions.

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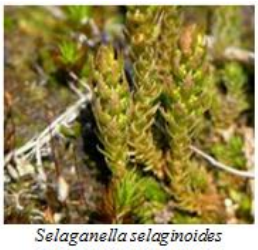
Appendix 1. Course Basic Competency and Grids of Integrated Instrument

Basic Competency	Course Subject	Questions No.	Integrated Indicator	
			Conceptual Understanding	Metacognitive skill
Understanding the basic concept of the characteristic of Pteridophytes that includes: Pteridophytes body structure, types of Pteridpophyte according to the spore's shape and size; providing examples of Pteridophytes Division and its roles	Characteristic of Pteridophytes	1	Re-stating a concept	Observing - Strategy (reason) arrangement used in learning the subject
		2	Classifying objects according to particular characteristics (in accordance with the concept)	Planning - Allocating the first priority items
	Characteristic of each sub-class of Pteridophytes	3	Providing examples and non-examples of the concept	Evaluating - Observing the righteousness of applied strategy
	Roles of Pteridophytes in daily life	4	Presenting concept in various representative formats	Planning - Arranging the objectives of learning the subject
	Characteristic of each sub-class of Pteridophytes	5	Developing the necessary or adequate requirements of a concept	Observing - Scoring and the appropriateness of applicable strategy usage determination
	Roles of Pteridophytes in daily life	6	Applying concept on encountered problems	Evaluating - Analysis of chosen/applied strategies
	Structure of Pteridophytes's body	7	Re-stating a concept	Planning - Allocating the first priority items.
Applying concept on the relationship of characteristics and body structure of Pteridophytes with its roles in the daily life	Types of Pteridophytes according to the shape and size of produced spore	8	Classifying objects based on particular characteristics (in accordance to the concept)	Observing - Scoring and the appropriateness of applicable strategy usage determination
	Types of Pteridophytes according to the shape and size of produced spore	9	Providing examples and non-examples of the concept	Evaluating - Observing the appropriateness of applied strategies
	Applying the characteristics of Pteridophytes	10	Presenting the concept in various representative formats	Planning - Allocating the first priority items.
	Structure of Pteridophytes's body and characteristic of each sub-class on Pteridophytes	11	Developing necessary and adequate requirements of a concept	Observing - Arrangement of strategies (reasons) applied in learning the subject
	Applying the roles of Pteridophytes in daily life	12	Applying concept on encountered problems	Evaluating - Observing the appropriateness of applied strategies

Note: the indicators of conceptual understanding of Biology were modified from Depdiknas (2016); the indicators of metacognitive skill were modified from *Metacognitive Awareness Inventory* (2014).

Appendix2. Development of conceptual understanding of Pteridophytes and students' metacognitive skill integrated questions

No	Question	Indicator	
		Conceptual Understanding	**Metacognitive skill**
1	On the classification level, there are differences on body structure and reproduction among Briophytes, Pteridophytes, and Spermatophytes. As for Pteridophytes, provide any reason why it is called *spored tracheophyte?*	Re-stating a concept	Observing - Arrangement of strategies (reasons) used in learning the subject
2	In Pteridophytes, there is a life cycle that shows two alternating heredities. Which one is more dominant and contribute to the formation of root, stem, and leaves of Pteridophytes?	Classifying objects based on particular characteristics (in accordance to the concept)	Planning - Allocating first priority items
3	Each class of Pteridophytes has its own distinct characteristics. One of them is the difference in leaf morphology. Explain the differences in leaf morphology between Psilophytinae and Filicenae, associate it with the reason why does Psilophytinae is called an ancient phylum in the old classification if viewed from the differences in leaf morphology between the two classes?	Giving examples and non-examples of concept	Evaluating - Observing the appropriateness of applied strategies
4	The more advanced civilization made the people think to go '*back to nature',* which emphasizing on the concept of sustainable development in empowering the environment. As a Biology teacher candidate, explain what steps will you take in applying the concept to the students. Includes some roles of Pteridophytes in supporting that concept.	Presenting concept in various form of representation	Planning - Arrangement of subject learning objective
5	Prepare an analysis concerning the differences of the appropriateness of ancient phylum from Psilophytiane in the old classification (Tjitrosoepomo, 1994) and Lycophyte in new classification (Smith *et al.,* 2006).	Developing necessary and adequate requirements of a concept	Observing - Scoring and the appropriateness of application determination for strategies that will be applied
6	 *Glechenia linearis*  *Acrostichum speciosum* If *Glechenia linearis* and *Acrostichum speciosum*is are suggested to be the substitute for rope used as binder or for woven material, 2016), which species will you use? Explain the reason based on the subject you have learned.	Applying the concept on encountered problems	Evaluating - Analysis of chosen/applied strategies

7	 *Licopodium clavatum*  *Selaganella selaginoides* Prepare an analysis on hereditary alternation of *Asplenium nidus* in protalium up to the spore formation, viewed from the leaf structure and habitat?	Re-stating a concept	Planning - Allocating first priority items.
8	The diversity of Pteridophyta can be seen, for example, from the diversity of body structure across species in one class, as well as the metagenesis and spore as the reproductive organs. Based on above illustration, make a difference cycle of metagenesis and spore produced between *Licopodium clavatum* and *Selaganella selaginoides*.	Classifying objects based on particular characteristic (in accordance with the concept)	Observing - Scoring and appropriateness of applied strategy application determination
9	When *Aspidium filix* and *Adiantum cuneatum* produce spores as reproductive organ, both plants experience alternating heredity. In your opinion, how is the relationship between the alternating heredity and the function of leaves in Pteridophytes?	Giving examples and non-examples of a concept	Evaluating - Observing the appropriateness of applied strategy
10	One of Pteridophytes species that becomes palm weed is *Davallia trichomanoides*. This plant causes concern among farmers due to its character that is easy to adapt with the environment surrounding the palm tree, thus decreasing the production of palm as well as their rejuvenation. Based on that fact, creates steps that contain suggestions for controlling the life cycle viewed from the fact and content you have learned (habitat, metagenesis, and body structure) that make *D.trichomanoides* is hard to control.	Presenting concept in various representation formats	Planning - Allocating first priority items.
11	In the past time, when the rubber farmers wanted to freeze the latex, they prepared *Selaginella caudate* and shaped it as a round container to filter latex, so that there would be no dirt left on the frozen latex. Based on that fact, explain the characteristics of that species as well as the body structure that is correlated with that role.	Developing necessary or adequate requirements of a concept	Observing - Arrangement of strategies (reasons) applied in learning the subject
12	If you have edema and is suggested to use *Equisetum* sp. as a herbal diuretic, how sure will you be to use that plant, considering the use of synthetic medicine that is more effective than the herbal one? Explain the reason!	Applying concept on encountered problem	Evaluating - Observing the appropriateness of applied strategy