



Identification of Formal-Post Formal Reasoning Prospective Biology Teachers on Three Aspects of Courses

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Abstract: This descriptive study aims to determine the reasoning of the formal-post formal operations of biology teacher candidates in three aspects of lectures. The research sample consisted of 76 students who took part in the 2019/2020 academic year lectures which were taken using the purposive technique. The sample consisted of 29 students in the General Biology practicum subject, 24 students in the invertebrates practicum subject, and 23 students in the vertebrate zoology practicum subject. The data was collected through a test technique using formal-post-formal operational reasoning questions that were developed by themselves and had met the constructive and empirical valid criteria. Data analysis regarding the level of formal-post formal operational reasoning was carried out using the percentage correct score technique obtained for each item so that the correct score was obtained from all students. The results showed that there was a difference in the percentage level of formal-post formal operational reasoning for each level of student lectures. The highest to the lowest level of reasoning was obtained by students who took the vertebrates zoology practicum course by 67%, invertebrates zoology practicum by 67%, and general biology practicum by 17%. Also, students' formal operational reasoning in each subject tends to be lower when compared to their post-formal operational reasoning. The most common indicators of formal reasoning among the three aspects of the lecture are proportional reasoning, and indicators that are lacking are probabilistic and correlational.

Keywords: Formal-Post Formal Operational Reasoning, Biology Teacher Candidate Students

Introduction

Biology as part of science essentially contains the concepts, laws, and principles of science. In teaching it, Biology is not only an activity to convey concepts or information from teachers to students, but in the form of activities to form knowledge and ways of thinking and reasoning. Thinking and reasoning scientifically are some of the characteristics of 21st-century skills to solve various kinds of problems (Zulfaidhah, et al., 2018). The reasoning is a concept of thought that comes from the general to a conclusion and forms a new statement from several previously known statements (Sutarno, 2014). Reasoning abilities can have important educational implications. Reasoning helps students to think logically (Hooda, et al., 2018). Therefore it is necessary to develop important competencies for 21st-century learning outcomes through various types of reasoning that are appropriate to the situation (Nuraini, et al., 2018).

The reasoning ability of students is currently still low. The low reasoning ability of students is due to the lack of teachers in applying reasoning skills in classroom learning

(Adriani, et al., 2015). Reasoning abilities generally receive emphasis in the teaching and learning process which can train students in thinking processes. Ausubel (Dahar, 2011) emphasizes that the learning process will occur when students can connect or link new information to relevant concepts contained in their cognitive structures. This kind of ability is closely related to formal reasoning or logical thinking. In logical thinking, students are required to understand or understand what is being taught, to know what is being communicated, and to be able to take advantage of its contents without having to connect with other things. Therefore, by realizing that science is growing rapidly, it is no longer possible for a teacher to be able to convey all facts and concepts to his students in the lesson maximally. Tawil (2008) states that in learning activities students are required to be able to think independently, both concretely and abstractly, accompanied by formal operational reasoning.

The importance of students having formal operating reasoning. It is believed that formal reasoning is essential for a person to be successful in the science and vocational fields. Several other researchers stated that students' formal reasoning abilities were an indicator of student success in mathematics and science (Cantu & Heron in Trifone, 1987). Students need this formal thinking ability in various lessons that require student activeness in thinking, especially in solving given problems. Therefore, improving students' formal thinking skills in the form of formal reasoning is very important to be able to understand various abstract concepts of biology properly.

Several studies reveal that the formal reasoning of prospective biology teacher-students is still low (Juhanda, et al., 2019; Murni, 2016; Ermiyanti, et al., 2016). Low formal reasoning skills cause students to be unable to understand and apply the concepts learned in the field in real situations. The results of field observations found that many prospective biology teacher students only know theoretically, but it is difficult to apply it in everyday life. Therefore in learning, students must be accustomed to using their reasoning skills to support their ability to understand the concept of material better and more effectively. So that it is hoped that students will not only memorize the theory but also be able to apply and reason about the formulation of the theory. Therefore, by mastering the science of biology which relies on reasoning and logic, students will be able to carry out their future lives with a more focused thinking process.

Reasoning ability in adults is called post-formal operative reasoning. In this reasoning, there are different levels of development from formal operational reasoning. In formal operational reasoning, there are several levels of development, including systematic reasoning, meta-systematic reasoning, paradigmatic reasoning, and cross paradigmatic reasoning (Commons, et al., 1982; Commons, et al., 2008; Commons & Richards, 2016). In this study, the post-formal operating reasoning studied was limited to systematic and meta-systematic. In systematic reasoning, students can differentiate frameworks for relationships between variables in an integrated system of tendencies and relationships. In meta-systematic reasoning, students act on the system. The system consists of formal operational relationships. Metasistematic actions include the activities of comparing, contrasting, changing, and synthesizing the system. Hokayem (2016) mentions that researchers think that systematic and systematic reasoning is difficult for middle and high-class students. Therefore it is important to know in advance these reasoning abilities.

During this time, practicum learning carried out in the biology education department tends to be dominated by the cookbook inquiry method (results of preliminary studies). Besides, lecturers monitor the progress of learning outcomes more focused on measuring the progress of the cognitive aspects and have never developed an assessment that equips students' reasoning skills, both formal and post formal. So that the reasoning abilities possessed by students are neglected. This study involved three different lectures, namely general biology practicum, invertebrate zoology practicum, and vertebrate zoology practicum to identify what level of formal-post formal reasoning students prospective

biology teachers have at the Universitas Muhammadiyah Sukabumi. The fundamental reason why this course is carried out is that it is related to one another, where general biology practicum is a basic subject and a prerequisite for introducing invertebrate and vertebrate zoology. So that they will have different levels of their experience which are expected to be different in their reasoning. The results obtained are expected to be used as a reference in selecting an appropriate learning model to train and develop students' formal-post formal reasoning skills.

Methods

This study is a descriptive study involving Biology education students, FKIP Universitas Muhammadiyah Sukabumi as the research population. The research sample included 76 students who took part in the lecture with the 2019/2020 academic year who were taken using a purposive technique. The sample consisted of 29 students taking the General Biology practicum, 24 students taking the invertebrate zoology practicum, and 23 students taking the vertebrate zoology practicum. The abilities studied included formal and post formal operational reasoning. The indicator of formal operating reasoning adopts Tobin and Capie (Valanides, 1996) which includes the ability to think proportionally, controlling variables, probability, correlational, and combinatorial. Meanwhile, the indicators of post-formal reasoning are limited to systematic and meta-systematic reasoning (Commons, et al. (1982). The data was collected through a test technique using 14 questions of formal-post-formal reasoning that were developed by themselves and had met the constructively and empirically valid criteria. Data analysis regarding the level of formal-post formal reasoning was carried out using the percentage of correct score technique obtained on each item, so that the correct value of all students was obtained. The equations used are as follows.

$$\text{Level of Reasoning} = \frac{\sum \text{Correct Score}}{\sum \text{Ideal Maximum Score}} \times 100$$

Furthermore, the level of reasoning is classified based on the interpretive criteria referring to Arikunto (2013) as follows.

Table 1. Interpretation Level of Reasoning

Percentage interval	Category
80-100	Very high
66-79	High
56-65	Enough
40-55	Low
0-39	Very low

Results and Discussion

This study informs about the initial identification of the level of formal-post-formal operational reasoning possessed by biology teacher candidate students at the FKIP Muhammadiyah University of Sukabumi. The results of data analysis from three levels of students who took practical courses showed that there were different levels of reasoning for formal-post formal operations. The results can be presented in Table 2.

Table 2. Achievement of Student's Formal-Post Formal Reasoning Indicators

Course Practicum	Semester	Percentage (%)	Category
General Biology	1	17	Very Low
Invertebrate Zoology	3	40	Low
Vertebrate Zoology	5	67	High

In Table 2, it can be seen that there are differences in the level of formal-post-formal reasoning for each level of student lecture. The highest to the lowest levels of reasoning were obtained by students who attended lectures of vertebrate zoology practicum, invertebrate zoology practicum, and general biology practicum. The existence of these findings indicates reasonableness because the reasoning ability of each individual is tiered based on the stage of development. Piaget (1964) argued that the intellectual development of each individual is adjusted to his age. In this case, students of general biology practicum have a low level of reasoning because they are still in semester 1. These students still have a level of thinking that is not yet complex when compared to students who have participated in the zoology practicum of invertebrates and vertebrates who are already in semesters 3 and 5. Besides that, they also do not have the experience in solving problems in biology further.

General biology practicum courses are basic courses that are prescriptive for the zoology practicum course for invertebrates and vertebrates. The characteristics of this course usually present basic concepts related to the classification of living things, which includes invertebrates and vertebrates. Besides, they are also believed to still carry or have high school learning patterns so it is suitable to be used to get information related to their formal-post-formal reasoning (Muis, et al., 2016). Based on table 1, it is shown that the achievement of formal-post-formal reasoning that is owned by students is still in the very low category, namely 17%. The achievements of each formal-post-formal operation indicator can be presented in Figure 1.

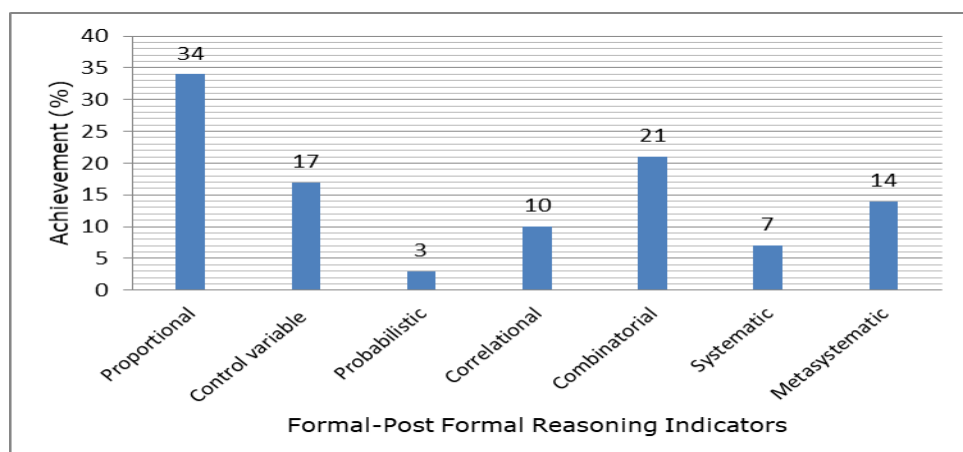


Figure 1. Student's Formal-Post Formal Operation Reasoning in General Biology Practicum Course

Figure 1 shows that in general biology practicum lectures, the indicators of formal reasoning that reach the highest percentage are proportional reasoning indicators. These results indicate that students have been able to understand and answer correctly the questions related to the proposition problems that are available in the questions even though they have never learned about this before. Nickerson (1985) argues that proportional reasoning can develop proportional relationships between weight and volume, transfer two dimensions to three dimensions, and estimate the size of the proportion of an unknown population. For probabilistic reasoning indicators, this reasoning reaches the lowest percentage. This reasoning deals with the problem of opportunity. Students can use the information to decide whether the conclusion is likely true or possibly incorrect. Nur (1991) argues that this reasoning starts from the development of the idea of opportunity. The concept of probability is fully mastered by students who are already in the formal operation stage, which is characterized by being able to distinguish things that are certain to happen and things that have the possibility of happening from the calculation of odds.

In the invertebrate zoology practicum course, the students' achievement of formal-post formal reasoning showed a low category, namely 40%. This percentage of achievement still needs to be improved to train students to develop better-thinking processes. The characteristics of this course have discussed the diversity of invertebrates in more depth when compared to studies in general biology practicum courses which only study the zoology of invertebrates in general terms. Therefore, a higher thinking process is needed to solve problems related to this invertebrate zoology practicum. The achievements of the formal-post formal operating reasoning indicators can be presented as follows.

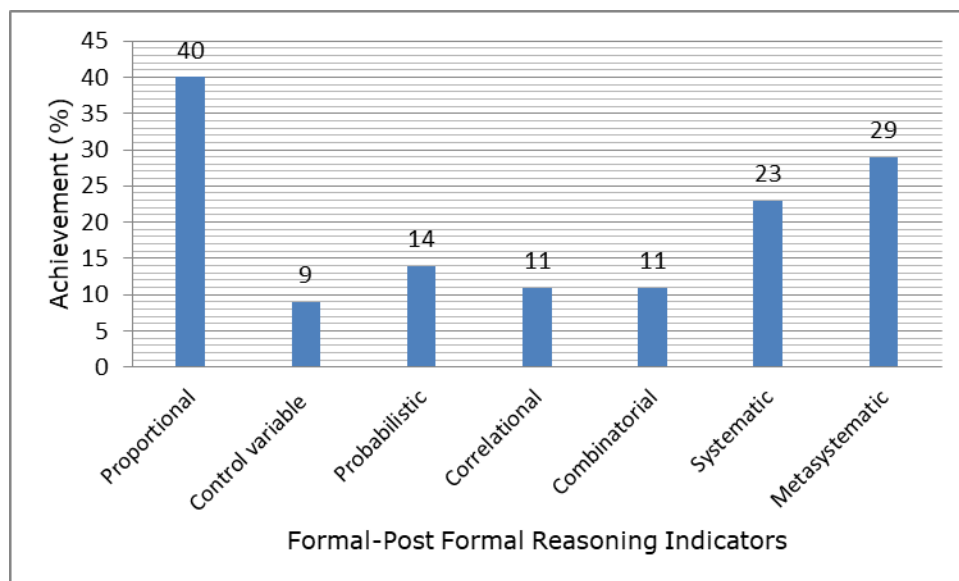


Figure 2. Student's Formal-Post Formal Operational Reasoning in the Invertebrate Zoology Practicum Course

Figure 2 shows that in the lecture on invertebrate zoology practicum, the proportional reasoning indicator has the highest percentage and the control variable reasoning indicator shows the lowest percentage. This shows that students can understand the problem of proportions well, but have not been optimal in working on problems that require them to control certain variables of a problem. Furthermore, Tairab (2016) said that the essence of this reasoning is choosing the right experimental arrangement, handling

more than two variables, and providing the correct explanation for the expected results in the experimental arrangement.

In the vertebrates zoology practicum (Table 1) shows the achievement of a high percentage of students' formal-post-formal reasoning compared to students who contracted general biology and invertebrate zoology practicum. Hooda, et al. (2018) argued that high reasoning abilities indicate high intelligence. Even though the characteristics of this course have a focus of study that is almost the same as the zoology of invertebrates, namely examining the diversity of vertebrates in more depth. Because the level of experience possessed by students who take this course allows the high achievement of post-formal formal reasoning that they have. The achievements of formal-post-formal operational reasoning in the vertebrate zoology practicum course can be seen in Figure 3.

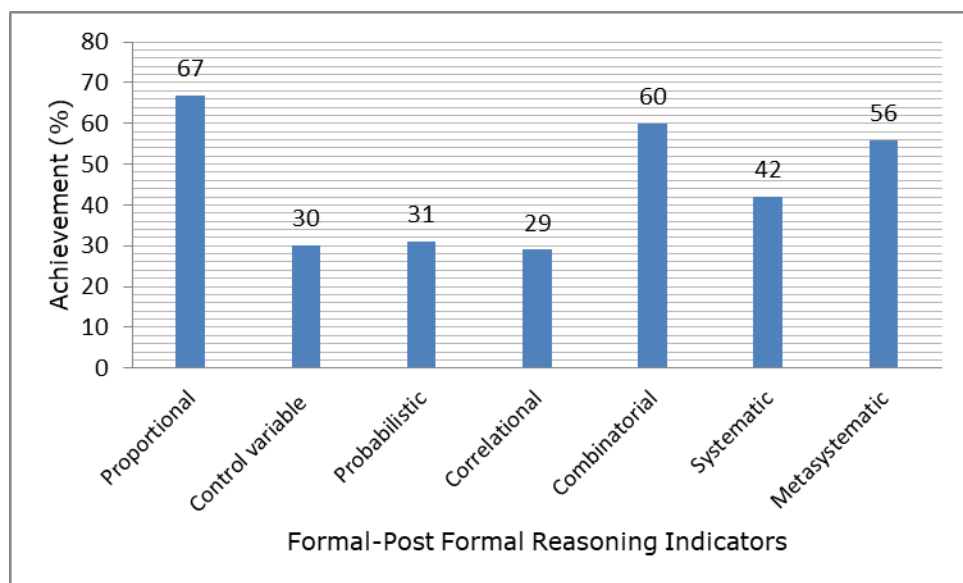


Figure 3. Student's Formal-Post Formal Operational Reasoning in Vertebrate Zoology Practicum Course

Based on Figure 3, it is revealed that vertebrate zoology practicum students get the highest percentage of reasoning on proportional indicators and the lowest on correlational indicators. These results indicate that students have been able to answer questions that contain proportions/comparisons, but have not been optimal in answering questions related to the relationship between variables. Whereas correlational reasoning is the reasoning used to identify and determine reciprocal relationships between variables (Lawson, et al., 1979; Lawson, 2000).

When viewed from the post-formal reasoning, the three levels of students who took part in the lecture showed that the meta-systematic reasoning indicator had the highest percentage achievement when compared to the systematic reasoning indicator. In systematic reasoning, students can differentiate frameworks for relationships between variables in an integrated system of tendencies and relationships. Whereas for meta-systematic reasoning, students can perform activities comparing, contrasting, changing, and synthesizing systems (Commons, et al., 1982; Commons, et al., 2008; Commons & Richards, 2016). In general, the mean formal and post-formal reasoning of students from the data above can be presented in the form of Figure 4.

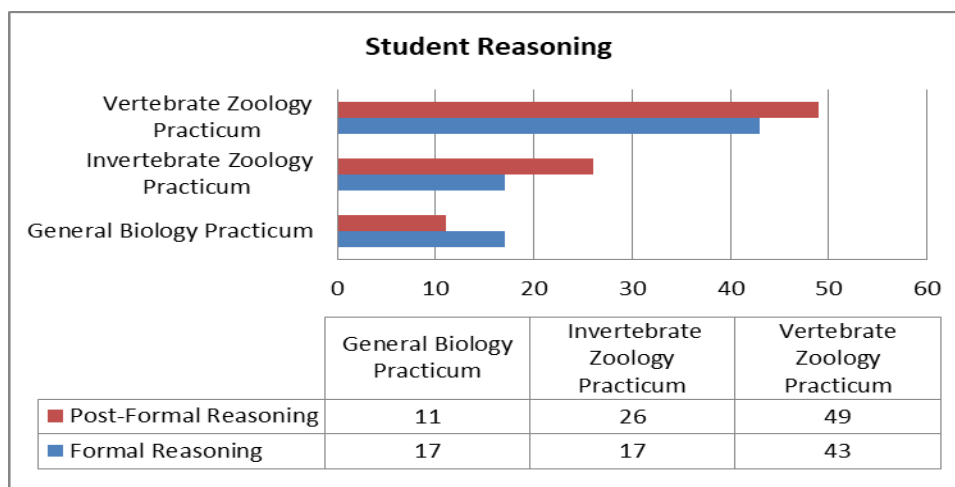


Figure 4. Average Achievement of Students' Formal-Post Formal Reasoning

Based on the picture above, it shows that the mean of students' formal operation reasoning in each subject has a percentage that tends to be lower when compared to their post formal operating reasoning. For example, in the practicum course of invertebrate zoology and vertebrate zoology, students have higher post formal operational reasoning compared to their formal operational reasoning. However, students who follow general biology practicum show different things, where they have higher formal reasoning compared to their post formal reasoning. This shows that these students have not been able to optimize their post formal reasoning abilities well because there are still many concepts that have not been understood in answering questions with post-formal content. Thahir (2018) explains that in formal thinking, one must be accustomed to doing complex, confusing, and challenging tasks. They can integrate conflicting facts and ideas and integrate new information with what they already know.

Meanwhile, the practicum of invertebrates and vertebrates shows the same thing where the reasoning of post formal operations is higher than the reasoning of formal operations. In post-formal operation, reasoning has a different level of development from formal operations. The main characteristics of the development of post-formal operations are: 1) being aware of relativity and the nature of knowledge that is not absolute; 2) accept contradictions as part of reality; 3) integrating all the contradictions found in one unit (Riegel, 1973; Commons, et al., 1982; Sinnot, 1982 in Meilinda, 2018). Therefore, successful learning requires a reasoning strategy. Indeed, the best way to develop reasoning skills is through challenging instruction that requires students to use old reasoning strategies and to discover or learn new ones (Martinez, 2000; Nickerson, 2004).

Conclusion

The reasoning of the formal-post formal operations of biology teacher candidate students in three aspects of the lecture has various percentage values. The order of attainment of formal-post formal reasoning from the lowest to the highest was found in students who attended general biology zoology practicum (17%), invertebrate zoology practicum (40%), and vertebrate zoology practicum (67%). The most common indicators of formal reasoning among the three aspects of the lecture are proportional reasoning, and indicators that are lacking are probabilistic and correlational.

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