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Analysis of students' conceptions of vertebrate diversity using concept maps

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Abstract

The concept of the characteristics of biodiversity is vital to be understood by students as a first step in managing and preserving the biodiversity. This study aimed to describe students' conceptions in vertebrate diversity and classification courses using concept maps. This research was conducted at one of the Biology Education Study Program Universities in Bogor, carried out in the even semester of 2023/2024, involving 42 participants. Data were collected through observation techniques with concept maps. The analysis process consisted of collecting information, simplifying information, presenting information, and drawing conclusions. The analysis results illustrate that students' conceptions of classification systematics, variability, phylogenetics, and preserving diversity and the environment show that they know the concept by 40.83%. The concept of the role of diversity in human life experienced the highest conception understanding of 54.61%. Students experienced many misconceptions about the concepts of characteristics, anatomy and morphology, genomes, and variability of biodiversity by 36.16%. Then 52.77% of students not knowing the concept of preserving diversity and the environment. The results of the concept map illustrate that most students still experience misconceptions and not knowing the concept of vertebrate diversity in detail. Therefore, training and strengthening concepts for students in classifying vertebrate animals are needed.

Abstrak. *Konsep mengenai karakteristik makhluk hidup penting untuk dipahami oleh mahasiswa sebagai langkah awal dalam mengelola dan melestarikan keanekaragaman makhluk hidup. Tujuan penelitian ini untuk mendeskripsikan konsepsi mahasiswa pada mata kuliah keanekaragaman dan klasifikasi vertebrata menggunakan peta konsep. Penelitian ini dilakukan di salah satu Perguruan Tinggi Prodi Pendidikan Biologi di Bogor, dilaksanakan pada semester genap tahun 2023/2024 dengan melibatkan 42 orang partisipan. Data dikumpulkan melalui teknik observasi dengan peta konsep. Proses analisis terdiri dari pengumpulan informasi, penyederhanaan informasi, penyajian informasi, dan penarikan kesimpulan. Hasil analisis menggambarkan bahwa konsepsi mahasiswa tentang sistematika klasifikasi, variabilitas, filogenetik dan konsep pelestarian keanekaragaman makhluk hidup dan lingkungan menunjukkan tahu konsep sebesar 40,83%. Konsep mengenai peranan keanekaragaman makhluk hidup bagi kehidupan manusia mengalami pemahaman konsepsi paling tinggi sebesar 54.61%. Mahasiswa banyak mengalami miskonsepsi pada konsep karakteristik, anatomi dan morfologi, genom, dan variabilitas makhluk hidup sebesar 36.16%. Kemudian 52.77% mahasiswa tidak tahu konsep pelestarian keanekaragaman makhluk hidup dan lingkungan. Hasil peta konsep menggambarkanan bahwa sebagian besar mahasiswa masih mengalami miskonsepsi dan tidak tahu konsep mengenai konsep keanekaragaman vertebrata secara detail. Oleh karenanya diperlukan latihan dan penguatan konsep bagi mahasiswa dalam klasifikasi hewan vertebrata.*

A. Introduction

A teacher's understanding of content is essential and is one of the competencies that must be possessed. A teacher who has a good understanding of the concept will quickly explain the concept to his students. According to Blyznyuk (2019), one of the competencies a teacher must have is mastery of the subject matter.

An educator making mistakes and misconceptions in delivering material will have fatal consequences for students. These errors and misconceptions will continue until the next generation. Generally speaking, misconceptions are caused by inadequate explanations, out-of-date reasoning, and ambiguous distinctions between theory and practice (Günther et al., 2019). If learners' conceptions are intuitive theories, then science learning cannot be seen as a process of adding or enriching prior knowledge (Vosniadou, 2019). Therefore, understanding concepts about science, including animal classification, must be taught as well as possible, especially to prospective educator students. This is so that the concepts they learn do not become a problem when they become teachers.

The concept of animal identification and classification must be considered to conserve and preserve biodiversity (Piñeros et al., 2022). Based on findings from several studies, learners understand the purpose of animal classification but find it challenging to apply it in practice. Even pre-service teachers in Northwest Ohio often use characteristics of locomotion and habitat to classify animals (Alanazi, 2018; Burgoon & Duran, 2012). In addition, most learners classify animals based only on the food they consume, their respiratory system, and their usefulness to humans (Chyleńska & Rybska, 2018). Thus, animal characteristics should be taught in detail to learners when classifying animals, and if not directed, some misinformation and alternative conceptions may result (Kılıç, 2016).

Misconceptions in science education, particularly in the concept of classification, are one of the main obstacles hindering student understanding. Several factors contributing to these misconceptions include ineffective teaching methods, lack of hands-on experience, and inadequate information sources (Suparno, 2013). Research indicates that these misconceptions can be addressed with appropriate teaching methods, such as the use of concept maps that help students organize and understand information better (Saragih, 2015).

Moreover, previous research shows that misconceptions often occur because students' prior knowledge is not considered in the learning process. Therefore, it is important to identify the causes of misconceptions in order to address them with appropriate learning strategies (Neta et al., 2013). In this context, concept maps can be used as tools to identify and correct student misconceptions, making learning more meaningful and effective (Labibah & Ernawati, 2017).

Various studies have shown that misconceptions are common problems in science education, including in the concept of animal classification. Findings from various countries indicate that students struggle with classifying animals, which is due to limited knowledge and inadequate experience (Randler & Heil, 2021; Ryman, 1974; Trowbridge & Mintzes, 1988).

Research in Taiwan shows that students have a limited understanding of animal classification, particularly from elementary to university levels. This indicates a need to improve teaching strategies and resources used in teaching animal classification (Chyleńska & Rybska, 2018; Yen et al., 2007).

One approach proposed to address this issue is the use of tiered diagnostic tests combined with tree thinking. This approach helps students understand the relationships between organisms through branching diagrams or cladograms (Novick & Catley, 2016; Omland et al., 2008). Thus, the use of concept maps and tree thinking can be effective solutions in addressing misconceptions in the learning of animal classification.

This study aims to describe students' conceptions in the course of vertebrate diversity and classification using concept maps. The novelty of this research lies in the application of concept mapping methods to identify and correct student misconceptions in the context of vertebrate learning in Indonesia. The scope of the research includes analyzing students' conceptions about systematic classification, variability, phylogenetics, anatomical and morphological characteristics, as well as the role of biodiversity in human life and natural resource conservation. Thus, this research is expected to make a significant contribution to improving students' understanding of vertebrate classification and reducing the common misconceptions in learning Vertebrate Diversity and Classification.

B. Material and method

The concept of Vertebrate Classification is fundamental to be understood by students because it relates to one another, for example, binomial nomenclature, morphometrics, taxonomy based on morphological characteristics, and genomes, which are basic concepts taught in other lectures. This research is descriptive with a qualitative approach, carried out at one of the Universities in Bogor in the academic year 2023/2024 in the Biology Education Study Program involving 42 students.

The limitations in this research include the following; first, participants in this study were limited to students in semesters IV, VII, and VIII; second, participants' perceptions were limited to the Learning

Outcomes in the Vertebrate Diversity and Classification course. Determining these limitations is expected to get a specific description and finally be able to describe the investigation results (Creswell & Guetterman, 2019).

Data were collected through observation techniques with concept maps. The observation technique is based on the completeness of the distribution of student knowledge statements grouped into criteria for knowing the concept, misconceptions, and not knowing the concept. These criteria were taken from the Novak & Cañas (2008) developed concept map.

The criterion of knowing the concept (KC) is fulfilled if there is a proposition/hierarchy/cross-linkage between concept statements equipped with connecting words to provide precise meaning. The criterion of misconception (M) is fulfilled if there is a concept statement that does not have the right relationship from the proposition/hierarchy/cross-linkage and is not equipped with the correct connective word, so it gives the wrong meaning or does not match the concept taught by experts. The criterion of not knowing the concept (NKC) is fulfilled if there are no propositions/hierarchies/cross-linkages between concept statements and are not equipped with connecting words, and if there are missing concepts.

The analysis process consisted of collecting information, simplifying information, presenting information, and drawing conclusions based on the technique of Miles et al. (2014). The collected information was then simplified and focussed on essential aspects relevant to the research objectives. The results of the analysis are presented in narrative form. Afterward, conclusions were drawn by analyzing the information and evaluating the activities based on the interviews conducted during the research. The qualitative percentage calculation using Formula 1.

$$NP = \frac{R}{SM} \times 100\% \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{Formula 1}$$

Description:
NP = Percent value of the concept map sought
R = Score obtained by the student
SM = Total score (Maximum score obtained)

C. Results and discussion

Based on the results of the study obtained, the results of students' conceptions of vertebrate classification are divided into several main concepts, including First, the conception of classification systematics, variability, and phylogenetics; Second, the conception of characteristics, anatomy, morphology, genome, and variability of biodiversity; Third, the conception of the role of the biodiversity for human life; Fourth, the conception of conservation of natural resources and the environment. The determination of the main concepts is adjusted based on the Study Programme Learning Outcomes and Course Learning Outcomes (CLO) compiled in the Semester Learning Plan. The percentage of the conception of vertebrate diversity and classification is presented in Table 1.

Table 1 Profile of students' conception of vertebrate classification based on learning outcomes

Scientific Conception	Percentage (%)		
	Knowing Concept	Misconception	Not Knowing Concept
CLO 1	40.83	35.12	24.04
CLO 2	29.12	36.16	34.72
CLO 3	54.61	22.76	22.63
CLO 4	31.84	15.39	52.77
Average	**39.10**	**27.36**	**33.54**

Description:
CLO 1 = Concept of classification systematics, variability, phylogenetics
CLO 2 = Concept of characteristics, anatomy and morphology, genome, and variability of biodiversity
CLO 3 = Concept of the role of the biodiversity in human life
CLO 4 = Concept of preserving the biodiversity and the environment

The results obtained based on the concept map of students regarding the concept of vertebrate classification show that they still need to learn the concept. The results of the tabulation of knowledge statements about the concept are based on reference criteria that know the concept, misconceptions, and not knowing the concept. These criteria are to determine students' level of understanding based on concept maps that have been made, and the grouping results can be seen in Table 1.

Generally, the average conception of students who know the concept is higher than students who have misconceptions and not knowing the concept. If based on more detailed concepts, students' conceptions of classification systematics, variability, phylogenetics, and the concept of preserving the biodiversity and the environment show that they know the concept by 40.83%. The concept of the role of the biodiversity for human life experienced the highest understanding of conception at 54.61%. Students experienced many misconceptions about the concepts of characteristics, anatomy and morphology, genomes, and variability of biodiversity 36.16%. Then 52.77% of students not knowing the concept of preserving the biodiversity and the environment. The high percentage can be caused by students needing to make the right cross-links between concepts with appropriate connective words.

In Figure 1, it is shown that among the four CLOs in the Vertebrate Classification material, the greatest misconception is about the concepts of characteristics, anatomy and morphology, genomics, and variability of living beings with a percentage of 36.16%, and the concept of classification systematics,

variability, and phylogenetics at 35.12%. The concept of the role of biodiversity for human life is at 22.76%, while the smallest percentage is the concept of biodiversity conservation and environment at 15.39%. The percentage of not knowing the concept of vertebrate classification indicates that the highest, 52.77% of students, do not know about the concept of biodiversity conservation and environment. The concept of characteristics, anatomy, morphology, genomics, and variability of living beings is at 34.72%. Then, the concept of classification systematics, variability, and phylogenetics is at 24.04%. The lowest percentage of not knowing the concept is 22.63% in the concept of the role of biodiversity for human life. Students who know the concept of classification systematics, variability, and phylogenetics are 40.83%. The concept of characteristics, anatomy, morphology, genomics, and variability of living beings is at 29.12%. The concept of the role of biodiversity for human life is understood by 54.61%. Finally, the concept of biodiversity conservation and environment is understood by 31.84% of students.

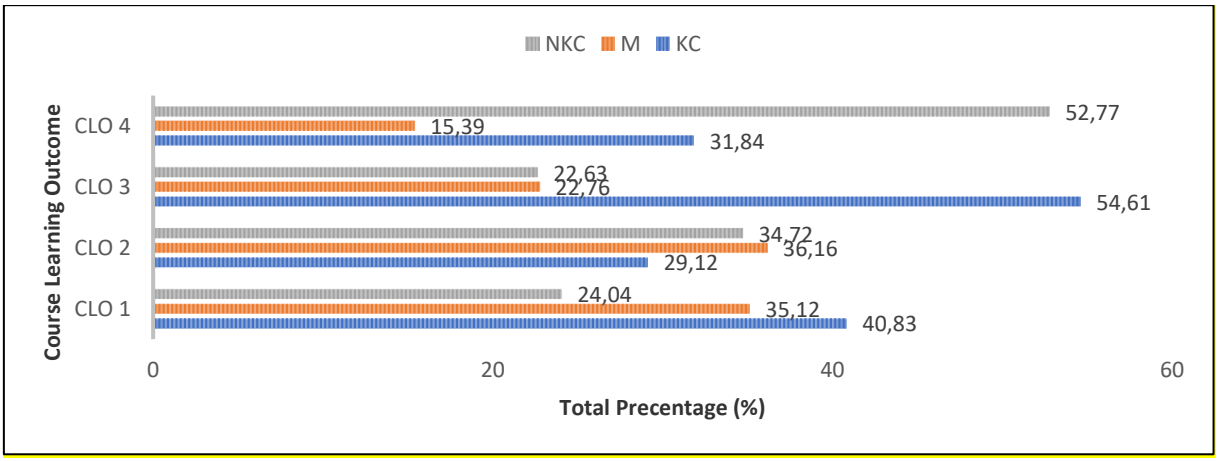

Figure 1 Percentage of student conceptions on each concept

Description:
NKC = Not Knowing Concept
M = Misconception
KC = Knowing Concept

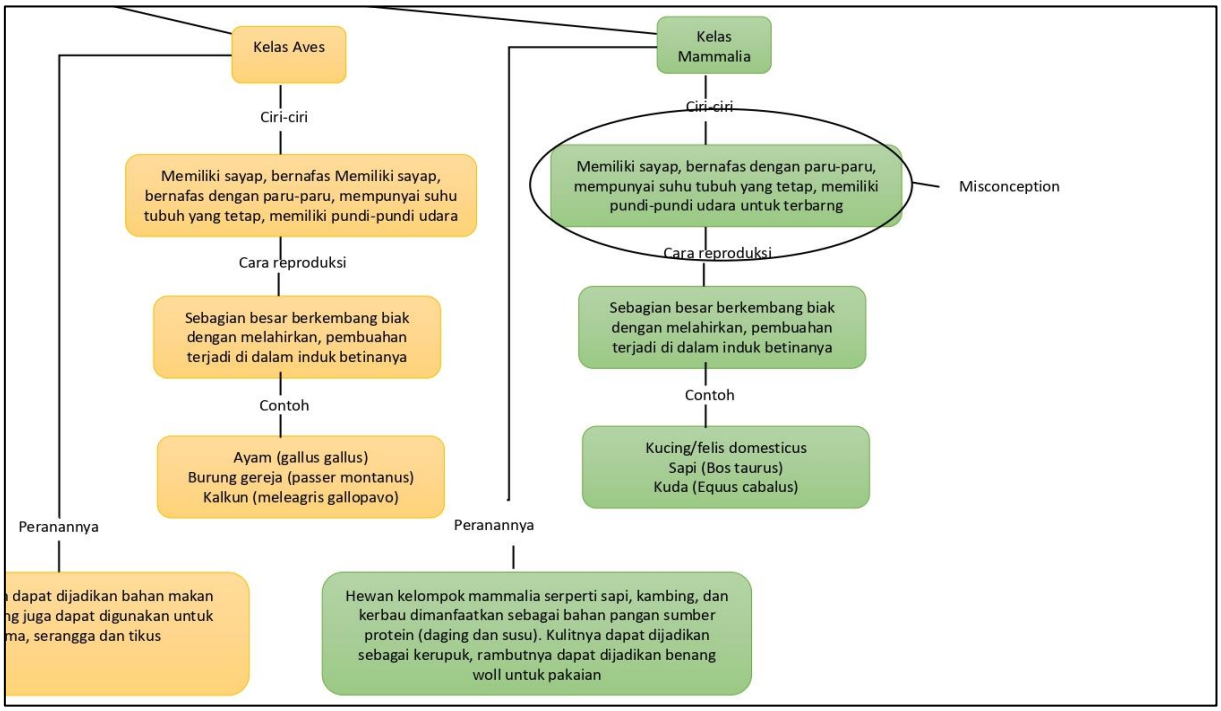

Figure 2 Example of student concept map (in Indonesian)

Based on the findings, it is found that students still experience misconceptions about the concepts of characteristics, anatomy and morphology, genomes, and variability of biodiversity. One example of the concept map results, students describe that mammals have air coffers, and the most misconception experienced by students is the incompatibility of propositions between concepts (Figure 2).

Many factors can cause misconceptions experienced by students. Information provided by media and textbooks can contradict scientific knowledge and cause students misconceptions (Barrow, 2002; Chyleńska & Rybska, 2019). In addition, The Animalia categorization covers a large amount of content, but it takes a little moment to learn (Nur'aini et al., 2015). Based on the results of concept maps, students mostly categorize the concept of vertebrate classification based on general characteristics, ways of reproduction, and roles for humans without being described in detail and even associated with genes. The combination of genetic and morphological data can complement each other and improve the taxonomic sequence (Bickford et al., 2007; Ikabanga et al., 2017).

The concepts of characteristics, anatomy and morphology, genome, and variability are essential because genomic identifications are useful in bioinformatics, as they can provide more accurate information and can overcome misconceptions in learning (Gomes et al., 2021; Martins & Tavares, 2020). Identifying morphological traits associated with genes can better understand the identified species and can help in breeding and conservation efforts (Li et al., 2020). Gene identification can help identify species based on their genetic information. Combining these two methods can provide more accurate results in species identification, especially in groups of organisms that are difficult to distinguish by morphology alone. This can help understand biodiversity and facilitate conservation efforts for endangered species (Young et al., 2019). Therefore, basic knowledge of morphological, anatomical, and genomic structures cannot be ignored by any student who will study vertebrate diversity.

The concept of morphological characteristics described in the concept map, in general, does not explain in detail the characteristics of each taxon. Each taxon has its own characteristics; this is related to evolutionary changes (Majeský et al., 2017). Most students only describe vertebrate diversity only up to the characteristics of the taxon class without elaborating on the species level. Each species has different morphological features (Xu, 2020). Understanding detailed characteristics is important for students to understand in practicum activities to identify biodiversity. These findings suggest that reinforcement is needed to support the learning process. Prototypes and complete learning media are one way that can help in learning animal classification (Hernawati et al., 2021).

Students also experience misconceptions about the concepts of classification systematics, variability, and phylogenetics. Some concept maps explain that fish are grouped into taxon classes. This is contrary to (Webb et al., 1981) that Pisces are classified into superclasses and then divided into Osteichthyes and Chondrichthyes classes. This classification is based on these biodiversity' physical and genetic characteristics. Classification aims to facilitate understanding biodiversity and the relationship between biodiversity in the universe (Cinici, 2013). Meanwhile, Yen et al. (2007) the binomial categorization system organizes and arranges scientific thinking across a number of biological fields, from evolution and ecology to anatomy and physiology. Phylogenetics contributes to understanding the evolutionary relationships between biodiversity and reconstructing kinship relationships between organisms (Silva et al., 2023).

This concept is vital for students to understand as prospective biology teachers. If a novice teacher has a positive attitude towards a particular animal, it will likely make it easier to contextually relate animal concepts in science learning. In addition, today's university students should be considered future environmental policymakers who have the right to voice their opinions on environmental issues (Tschentscher, 2016; Wagler, 2010). So, biology educators should make their students appreciate and conserve biodiversity for the future.

Based on the concept maps made by students shows that most students need to elaborate important concepts into concept maps. This illustrates that students' knowledge of the concept still needs to be improved. Various studies explain the importance of knowledge and understanding of the conservation of biodiversity. According to Coracero et al., (2022) the importance of knowledge and awareness of biodiversity is a form of prevention and conservation.

Conservation education will not only help learners to become lifelong learners but will also help them contribute to a thriving environment in the future (Birdsall & Kelly, 2022). Understanding vertebrate diversity is a fundamental requirement for developing attitudes appropriate to its conservation, emphasizing the importance of biological literacy, especially in education (de Oliveira et al., 2019, 2020). Local living organisms and contextualization are important approaches to help learners enjoy science teaching, and teachers should also determine appropriate learning strategies to protect and conserve local resources (Tupas, 2019). Nature-based education and hands-on experiences in nature can improve students' knowledge, attitudes, and behaviors related to preserving and conserving biodiversity (Ballantyne et al., 2018; Ballantyne & Packer, 2002).

Various findings from different countries indicate that students experience difficulties in classifying animals, which are caused by limited knowledge and inadequate experience (Randler & Heil, 2021; Trowbridge & Mintzes, 1988). Students have a limited understanding of animal classification, especially from elementary school to college levels (Yen et al., 2007). Similar findings were also found among fourth, seventh, and eighth semester students at a university in Bogor, indicating that generally, learning about the diversity and classification of vertebrates still involves misconceptions and a lack of conceptual understanding. These findings highlight the need to enhance teaching strategies and resources used in teaching animal classification.

D. Conclusion

Based on the study's results, it can be concluded that students' conceptions of classification systematics, variability, phylogenetics, and preserving the biodiversity and the environment show that they know the concept of 40.83%. The concept of the role of the biodiversity for human life experienced the highest conception understanding of 54.61%. Students experienced many misconceptions about the concepts of characteristics, anatomy and morphology, genomes, and variability of biodiversity 36.16%. Then 52.77% of students not knowing the concept of preserving the biodiversity and the environment. In general, it illustrates that in learning the diversity and classification of vertebrates, students still experience misconceptions and not knowing the concept. Students mostly categorize the concept of vertebrate classification based on general characteristics, reproduction methods, and roles for humans only. Furthermore, participants should be given more practice in animal classification and motivated to find relevant reference sources.

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