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Undergraduate Students' Initial Ability in Understanding Phylogenetic Tree

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Abstract. The Phylogenetic tree is a visual representation depicts a hypothesis about the evolutionary relationship among taxa. Evolutionary experts use this representation to evaluate the evidence for evolution. The phylogenetic tree is currently growing for many disciplines in biology. Consequently, learning about the phylogenetic tree has become an important part of biological education and an interesting area of biology education research. Skill to understanding and reasoning of the phylogenetic tree, (called tree thinking) is an important skill for biology students. However, research showed many students have difficulty in interpreting, constructing, and comparing among the phylogenetic tree, as well as experiencing a misconception in the understanding of the phylogenetic tree. Students are often not taught how to reason about evolutionary relationship depicted in the diagram. Students are also not provided with information about the underlying theory and process of phylogenetic. This study aims to investigate the initial ability of undergraduate students in understanding and reasoning of the phylogenetic tree. The research method is the descriptive method. Students are given multiple choice questions and an essay that representative by tree thinking elements. Each correct answer made percentages. Each student is also given questionnaires. The results showed that the undergraduate students' initial ability in understanding and reasoning phylogenetic tree is low. Many students are not able to answer questions about the phylogenetic tree. Only 19 % undergraduate student who answered correctly on indicator evaluate the evolutionary relationship among taxa, 25% undergraduate student who answered correctly on indicator applying concepts of the clade, 17% undergraduate student who answered correctly on indicator determines the character evolution, and only a few undergraduate student who can construct the phylogenetic tree.

1. Introduction

The phylogenetic tree is a diagram that depicts evolutionary relationships among a group of the organism (Taxa) that are believed to have a common ancestor [1][2][3]. A phylogenetic tree is an important tool for organising knowledge about the diversity of organism and a tool for structuring classifications, and for providing insight into events that occurred during evolution [4].

Phylogenetic trees are currently growing in nearly all disciplines of biology [5]. Phylogenetic used by researchers to answer fundamental questions about the history and diversity of life on earth and applied by the researchers, such as in the field of human epidemiology, antibiotic resistance, artificial selection for the domestication of animals and plants [6][7]. Therefore, studying about phylogenetic trees has become an important component in the biology education and an interesting area for biology education research [8]. The ability to understand and make sense of phylogenetic trees (referred to as cladistics thinking/tree thinking) is an important skill for biology students [9]. Unfortunately, students

often are not taught how to make sense of evolutionary relationship that is depicted in the diagram. Students are also not provided with information regarding the underlying theory and process of the phylogenetic tree [9]. Therefore, no wonder many undergraduate students have misconceptions in understanding phylogenetic tree [9][10] and students have difficulty in interpreting, constructing, and comparing among the phylogenetic tree [2][10][11]. The researcher has an opinion that understanding phylogenetic tree is a complex cognitive task and without proper scaffolding, many students cannot transfer the empirical data into visual structure [12]. The purpose of this study was to investigate the initial ability of undergraduate students in understanding and reasoning the phylogenetic tree. Information obtained from this study can give an idea to educators in developing undergraduate students' skill to understanding and make sense of the phylogenetic trees.

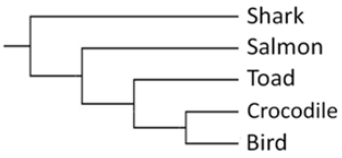
2. Research methodology

2.1. Research subjects

The research has been conducted on Program Studi Pendidikan Biologi UIN SGD in Bandung West Java. The subjects were 87 undergraduate students enrolled in vertebrate zoology course. All students were a sophomore.

2.2. Methods, data collection and analysis techniques

The method of this study is descriptive research. Data collection technique used was tests and questionnaire. Tests conducted to reveal undergraduate students' initial ability in understanding and reasoning phylogenetic tree. Subject received multiple choice questions and essay. Each question is adjusted with tree thinking skill modified from Novic and Catley[13]. It is describing the character of a taxon from the phylogenetic tree, determining the character of evolution, comparing the type of the phylogenetic tree, applying the concept of clade, evaluating relative evolutionary relatedness, determine the common ancestor between two or more species (MRCA/Most Recent Common Ancestor) and built a phylogenetic tree. Furthermore, the correct answer for every question made a percentage. Sample question can be seen in Figure 1.



Observe the phylogenetic tree above what animals have the closest evolutionary relationship? Why, tell your reason!

(a)

	vertebrate	Bone	Four limb	Amnion	Hair	Two post-orbital fenestra
Shark	Yes	No	No	No	No	No
Mackerel	Yes	Yes	No	No	No	No
Frog	Yes	Yes	Yes	No	No	No
Rabbit	Yes	Yes	Yes	Yes	Yes	No
Monkey	Yes	Yes	Yes	Yes	Yes	No
Crocodile	Yes	Yes	Yes	Yes	No	Yes
Peacock	Yes	Yes	Yes	Yes	No	Yes

Observe the table that contains character for some animals above, create a phylogenetic tree base on data in the table!

(b[17])

Figure 1. Sample question to investigate undergraduate students' initial ability in understanding and reasoning phylogenetic tree

3. Results and Discussion

Undergraduate students' initial ability in understanding and reasoning phylogenetic tree shown in Figure 2.

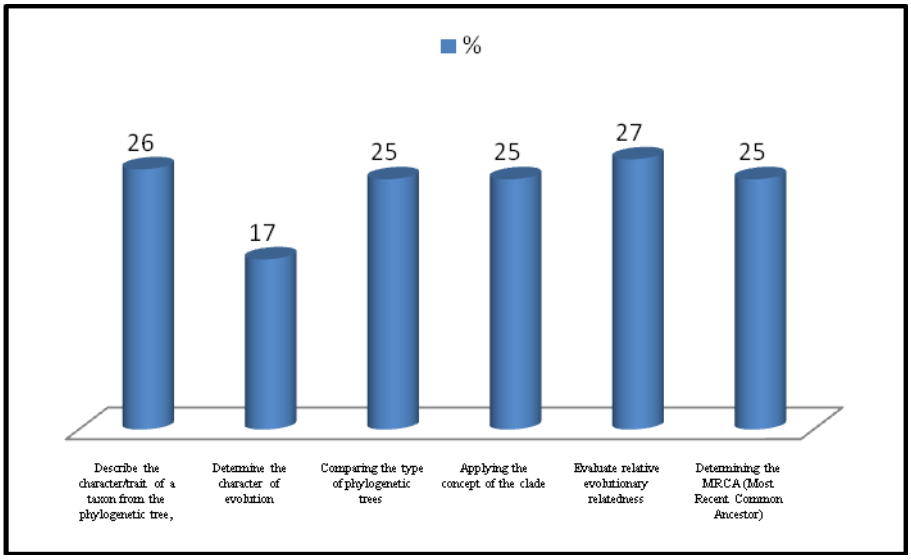


Figure 2. The percentage of undergraduate student' initial ability in understanding and reasoning phylogenetic tree

Based on Figure 2, undergraduate students' initial ability in understanding and reasoning phylogenetic trees are low. Students had difficulty answering the questions that we provided. Undergraduate students who answered correctly on each tree thinking skill, none up to 30%. The lowest percentage (17%), obtained from the indicator tree thinking skill namely determine the character of evolution. Students have difficulties in determining character evolution such as synapomorphy and autapomorphy from a phylogenetic tree provided because they do not understand the definition of each character evolution and often confuse one character with another character.

Base on Figure 2, the highest percentage (27%), obtained from the indicator tree thinking skill namely to evaluate the evolutionary relationship among taxa. Further, we ask about the indicators to evaluate the evolutionary relationships between taxa (question shown in Figure 1a), and most students answered incorrectly. According to them, an animal that has the closest evolutionary relationship is a shark and salmon, because of sharks and salmon both belong to a group of fish (Pisces), both live in the water, and their position in the phylogenetic tree is near. Some students answered the question correctly, but not with the reasons. Some students answered correctly, but less precise reasons, such as crocodiles and birds have a close evolutionary relationship because their position in the tip a phylogenetic tree is adjacent. Only a few students were answered correctly and give a good reason. Previous studies show that college students have misconceptions about reading the phylogenetic tree, among these students thought similarity indicates relatedness [14]. The species are drawn closer together at the tips of the tree were more closely related to each other than those drawn farther apart [11,][15], taxa relatedness is determined by a prior knowledge and not provided by phylogenetic trees]16][13].

Undergraduate students' initial ability in constructing the phylogenetic tree was not much different from reading the phylogenetic tree. Only a few students were able to build the phylogenetic tree based on the data provided. Figure 3, 4, and 5 below presents the answers of students in constructing the phylogenetic tree based on data provided (Figure 1b).

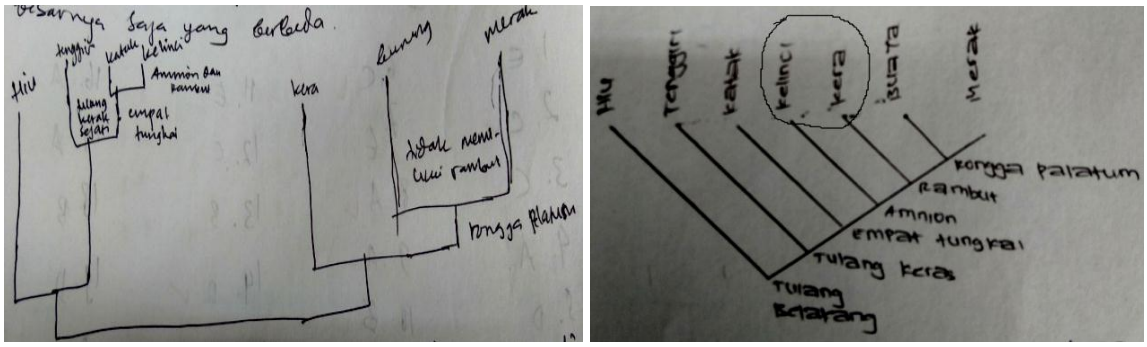


Figure 3. Incorrect relatedness

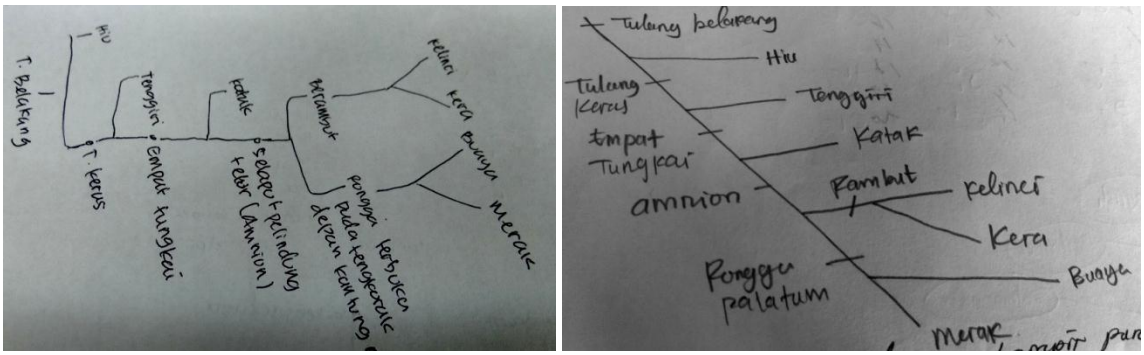


Figure 4. Unusual feature

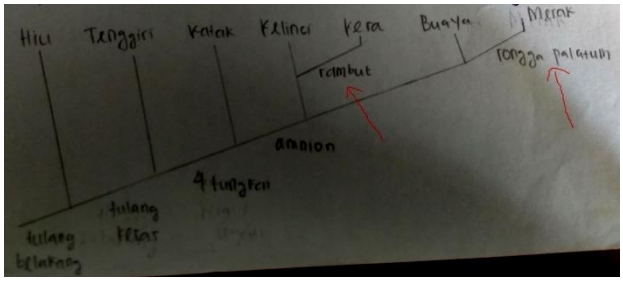


Figure 5. Incorrect placing a trait

Phylogenetic trees can be presented in a many ways, as shown in Figure 6, but some students draw the phylogenetic tree with an unusual figure (Figure 4). Based on Figure 3. many students draw phylogenetic trees incorrectly especially placing taxa in the tip phylogenetic trees, so phylogenetic trees that they draw doesn't describe the actual evolutionary relationship (incorrect relatedness). For example, in Figure 3a. Incorrect relatedness showed among mackerel (*tenggiri*), frog (*katak*) and rabbit (*kelinci*), and in Figure 3b. Incorrect relatedness showed among rabbit (*kelinci*) and monkey (*kera*). Based on Figure 5. The student was incorrect in placing trait (fur = rambut); therefore, the fur only belong monkey (kera), and rabbit (kelinci) don't have fur.

Results of student answer as shown in the image above, not much different from previous studies, that common major construction error was contemporary descent (extant taxa are descended from other extant taxa), empty branches, extra nodes, incorrect relatedness, incorrect traits[18].

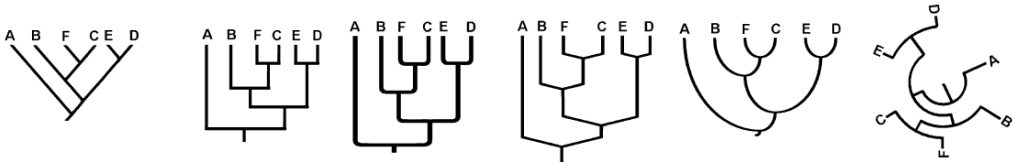


Figure 6. Six common figure to depicting phylogenetic trees using rooted trees[14]

These results were supported by the results of the questionnaire given to the students that 62% students stated no to the question "*Are you able to read the phylogenetic tree to see the evolutionary relationships among organisms?"* and 86% stated "no" to the question "*Are you able to build the phylogenetic tree base on data provided?"*. Base on information from the questionnaire indicates that students lack knowledge of the phylogenetic tree, although 95% of the students admitted that they had previously been taught about the phylogenetic tree in Invertebrate Zoology and Botany Cryptogamae courses.

4. Conclusion

Based on the results and discussion, it can conclude that generally, undergraduate students' initial ability in understanding phylogenetic is low. Many students are not able to answer questions about the phylogenetic tree. Undergraduate students have to experience difficulties, especially in constructing a phylogenetic tree. Thus, it is necessary to plan great strategy in solving the problems. The results provide insight to researchers and educators to develop learning or lab for fostering undergraduate students in understanding the phylogenetic tree.

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