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Implementation of Phylogenetic Worksheet to Improve Students' Tree Thinking and Critical Thinking Skills on Spermatophyte Classification

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Abstract
Recent research shows that students' ability to read and create phylogenetic trees (tree thinking) is low, meanwhile phylogenetic analysis has become one of the demands on the 2016 version of the 2013 curriculum. Learning using phylogenetic trees is thought to be able to train critical thinking skills as the demands of the 21st century. However, the use of phylogenetic worksheets, especially on Spermatophyte classification, is often skipped in learning activities at School. This research aims to determine the improvement of students' tree thinking and critical thinking skills after implementing phylogenetic worksheets in Spermatophyte learning as a visual representation of tree-thinking abilities. This research type was experimental research with one group pretest posttest design that involving 29 students. The research data collection methods were test and interview. The research instruments that used are 25 multiple choice questions of tree-thinking test instrument and 10 essay questions of critical thinking test instrument. Data then analyzed by N-Gain test. The interview was conducted to obtain supporting data. The results showed that learning by implementing phylogenetic worksheets was quite effective in increasing critical thinking skills and tree-thinking skills with an average increase of both in the medium category. As a result, the spermatophyte classification learning using phylogenetic worksheet can be used as an alternative learning activity because it can improve tree thinking and critical thinking skills.

Keywords: Tree thinking, critical thinking, worksheet, phylogenetic

INTRODUCTION

Indonesia is referred to as a mega-biodiversity country (Rintelen et al., 2017). However, currently, biodiversity in Indonesia continues to decline. Data shows that extinction averaged around 100,000 species per year (Kusmana & Hikmat, 2015). In fact, many species that have not been scientifically identified are in danger of extinction. Because of this, the education sector has a stake in protecting and preserving biodiversity, by providing students with the ability to identify, classify and understand the kinship of species so that they can identify and monitor the variety of living things found on earth (Hidayat, 2021b). It can be stated that by enabling students to recognise, categorise, and comprehend the relationships between species so that they can recognise and keep track of the variety of living creatures on earth, the education sector has a stake in maintaining and safeguarding biodiversity.

Biodiversity material at the senior high school level includes the classification of animals and plants. In plant classification material, one of the sub-materials is the classification of spermatophyte. Spermatophyte classification material is one of the materials that is considered difficult because it contains a lot of memorization and terms (Hidayat, 2017). In addition, researchers feel that many educators use inappropriate methods such as the lecture method in delivering classification material. This affects the attention, thinking ability, and competence of students towards the material. Students' learning difficulties can be overcome by using hands-on learning methods such as applying worksheets that require students to play an active role in learning activities (Ekwueme et al., 2015). Also, phylogenetic trees provide an efficient framework to organize students' growing knowledge of biodiversity (Dees et al., 2017). So, the researchers suspect that the right method to be used in learning spermatophyte classification is using a phylogenetic tree worksheet so that it is expected to be able to overcome students' learning difficulties.

A phylogenetic tree, also known as a phylogeny, is a diagram that depicts the lines of evolutionary descent of different species, organisms, or genes from a common ancestor so it is very useful for organizing knowledge of biological diversity, for structuring classifications, and for providing insight into events that occurred during evolution. Understanding a phylogeny, its construction and its interpretation, is at the core of the modern comparative method in biology (Staton, 2015). The ability to understand phylogenetic trees is referred to as tree thinking ability (Mahbubah et al., 2017). The use of phylogenetic trees as a learning media that represents the ability of tree thinking in Indonesia is still rarely used. However, in fact this ability has become a requirement in the national curriculum in Indonesia since 2016 in biology material for 10 graders listed in *Kompetensi Dasar* (KD) points 4.3 and 4.8. Apart from that, tree thinking ability is one of the key components that must be possessed in 21st century scientific literacy (Novick & Catley, 2016). In line with that, the use of phylogenetic trees has a significant effect on students' interpretation and construction abilities (Dees et al., 2017). However, students' tree thinking skills are still low (Julaeha, 2019). Many students read phylogenetic trees only at the ends (usually from left to right) and interpreted the species on the left to be more "primitive" than the species on the right (McCullough, et al., 2020).

Learning how to use phylogenetic trees stimulates critical thinking skills which are demands of the 21st century (Hidayat, 2021a). Critical thinking is high-level thinking or often also called complex thinking processes (Facione in Fisher, 2009). One of the results of the study explains that a person's critical thinking skills can also develop, one of which is with activities that can develop observational abilities (Sartorelli et al., in Hanaswati, 2000). Given the importance of phylogenetic learning, the low ability of tree thinking and the demands of critical thinking skills, this research was conducted with the aim of increasing students' tree thinking skills and critical thinking skills in the Spermatophyte classification material by implicating a phylogenetic worksheet.

METHOD

This research was an experimental research with one group pretest posttest design. This research aimed to determine the increase in students' tree-thinking skills and critical thinking skills after participating in Spermatophyta classification learning using phylogenetic worksheets. The research was carried out in the biology subject at a Bandung public school in March 2022. The research on 29 10^{th} grade students was conducted in three meetings. Each meeting was held for 3 study-hours with 1 study-hour equal to 45 minutes of offline class. The research data was in the form of quantitative and qualitative data. Quantitative data was collected using a tree thinking test instrument totaling 25 multiple choice questions and a critical thinking test instrument totaling 10 descriptive questions as shown in Table 1. In this case the critical thinking ability refers to the Norris-Ennis indicator. Meanwhile, qualitative data was collected using interview guidelines as supporting data. The data was collected before and after learning activities. The ability data was tabulated and grouped into five categories in the form of percentages. These categories refer to Arikunto (2013), for level very high (81-100), high (61-80), moderate/sufficient (41-60), low (21-40) and very low (0-20). Furthermore, with the help of the SPSS application, the N-Gain test was carried out. The N-Gain values obtained are interpreted referring to Hake (1998) with high (<g>≥70), medium (0.70 > <g> > 0.30) and low (<g> ≤ 0.30) categories.

Table 1. Indicators of Ability Tree Thinking and Critical Thinking

Indicator	
Critical Thinking Skills	
Elementary clarification	Focusing questions Analyze arguments Ask and answer questions
Basic support	Observe and consider the results of observations
Inference	Make deductions and consider the results of deductions Make inductions and consider the results of inductions
Advance clarification	Define terms and consider definitions Identify assumptions
Strategy and tactics	Decide on an action
Tree Thinking Skills	
Specifies the order of appearance	
Define common features	
Define characteristics	
Define outgroups	
Reconstructing the phylogenetic tree topology	
Determine kinship	
Defining groups (clades)	
Specifies the type of branch	

FINDINGS AND DISCUSSION

After doing the research, the results of the pretest and posttest of tree thinking skills were analyzed descriptively (Table 2). Based on Table 2, the average score of the pretest for tree thinking skills obtained by students was 32.13. The values are spread from 8.00 to 68.00. The standard deviation is 12.35. While the average posttest score for tree thinking skills obtained by students is 74.06. The values are spread from 36.00 to 96.00. The standard deviation is 13.50. The posttest average score of students' tree thinking skills is higher than the pretest average score.

Table 2. Recapitulation of Student Pretest and Posttest Data on Tree Thinking Ability

Counted Factors	Pretest	Posttest
The number of students	29	29
Lowest score	8.00	36.00
Highest score	68.00	96.00
Average	32.13	74.06
Ideal score	100	100
Standard deviation	12.35	13.50

Researchers suspected the low initial ability of students' tree thinking from the start, because of the students had never learned how to construct and read phylogenetic trees (tree thinking) previously. In other words, phylogenetic analysis is a new thing for students. It called new thing is because the demands for phylogenetic analysis abilities have also just been established as basic competencies that students must have in the 2013 version of the 2016 curriculum. Therefore, it is only natural that the data on initial tree thinking abilities shows this. The low initial ability of students' tree thinking is in line with other research that students who have not been introduced to phylogenetic trees often misread phylogenetic trees (Blacquiere & Hoese, 2016). Research conducted by Fuadiyah et al. (2021) also found that students' initial tree thinking abilities, especially in analyzing and interpreting cladograms, were still low. Even at the student level, they often experience misconceptions about tree thinking. Misconceptions that often occur in reading and making phylogenetic trees when studying evolutionary material are reading tips, node counting, ladder thinking, and similarity equals relatedness (Kummer et al., 2016).

Apart from being analyzed descriptively, the tree thinking ability of each student was analyzed for the magnitude of the increase through the N-Gain test. The magnitude of the increase is interpreted and accumulated for each category in percent form (Diagram 1). Based on Diagram 1, the data distribution of students' tree thinking ability improvement consists of; 10.34% of students are in the low category, 48.28% are in the medium category and 41.38% are in the high category. So, it can be said that most students experienced an increase in tree thinking skills in the moderate category. Thus, it can be said that the implication of phylogenetic worksheets is quite effective in increasing students' tree thinking abilities in Spermatophyte classification material.

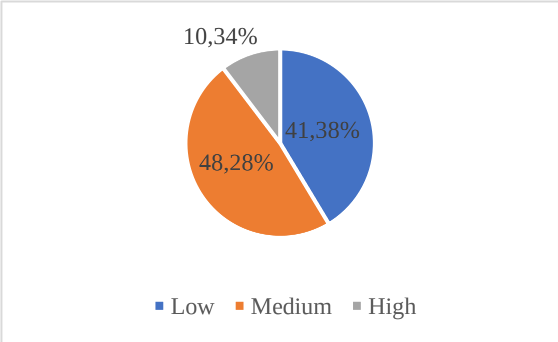

Diagram 1. Percentage of Categorization of Students' Tree Thinking Ability Improvement

The magnitude of the increase in students' tree thinking skills was due to several factors, ie. interest, seriousness, absorption, learning methods and the language used in learning activities. Based on the results of the interviews proccess, that the learning activities is fun because they were learning new things and does not require complicated materials, because they only bring species from around the house and are identified directly at school. Based on this, the high ability of students' tree thinking is thought to be due to students' interest in the learning activities that are applied. Other researchers found that the simple practicum learning method had a significant positive effect on students' learning interest (Fitri et al., 2021). Also, Rusmiati (2017) shows that interest in learning can improve learning outcomes. The seriousness of students in participating in learning activities is also a factor in increasing students' tree thinking skills. Relevant to the results of other studies, that the higher the students' seriousness in learning, the higher their learning outcomes (Fitriwati, 2018). In addition to seriousness, different students' absorption abilities affect the improvement of tree thinking skills. In line with the results of other studies, they show that the absorption and learning outcomes of students are affected by the learning methods and programs applied, as well as student participation in learning (El-Hilali et al., 2015). The high score of students' tree thinking skills as a result of learning from the use of phylogenetic worksheets is in accordance with other studies which show that hands-on learning using worksheet activities affected learning outcomes with an effectiveness of 60% (Aprilla et al., 2016). Improving tree thinking skills is also due to learning to use visual language, for example diagrams. The diagram in this case is in the form of a phylogenetic tree which helps students understand non-verbal languages. Supriadi (2017) explains that using visual learning media in learning Science is important.

The score of each student obtained can also provide information related to the average percentage of students' tree thinking ability in each indicator (Diagram 2).

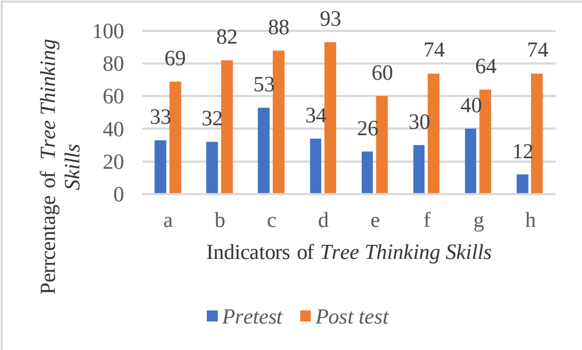

Diagram 2. Percentage of Pretest and Posttest Scores for Each Student's Tree Thinking Ability Indicator

Based on the results of data analysis for each student's tree thinking pretest and posttest questions, the tree thinking skills of each student was obtained for each indicator (Diagram 2). The highest increase of the student's tree thinking skills showed in the indicator determining the out group, 0.89 (high). It could be happened because most students were able to distinguish which taxa had the most similar or different characteristics from other taxa. Supported by the results of the interviews, students explained that the easiest ability was to determine outgroups. According to him, an out group is an organism that is most different from other organisms because it only has the fewest similar characteristics or even does not have all the characters observed. While the lowest increase showed in the ability to determine the group (clade) that scored 0.32 (moderate). This is because students do not understand which ancestors determine whether some taxa are in one group or not and which common ancestor for all species identified, because this is rarely written in a phylogenetic tree. Supported by the results of the interviews, students' understanding of the members of a monophyletic group consists of two species and finds it difficult to determine whether a line is included in a monophyletic group or not. In line with research conducted by Sa'adah & Hidayat (2017) that students still experience difficulties in reading and constructing phylogenetic trees such as determining sister groups (monophyletic and related groups) from available data.

Critical Thinking Skills

After conducting the research, the results of the pretest and posttest of critical thinking skills were analyzed descriptively (Table 3). Based on Table 3, the average pretest score for students' critical thinking skills was 30.24. The values are spread from 11.10 to 51.90. The standard deviation is 9.64. Meanwhile, the posttest average score for students' critical thinking skills was 71.41. The values are spread from 48.10 to 88.90. The standard deviation is 10.60. The posttest average score for students' critical thinking skills is higher than the pretest average score.

The low initial ability of students to think critically is thought to be due to the lack of readiness of students to start learning activities. This is in accordance with (Chorrojprasert, 2020), that the students' readiness factor in this case includes physical and psychological is a factor that contribute to their achievements. Physical factors include unproductive physical/body conditions, such as fatigue or illness. While psychological factors include unfavorable psychological conditions such as depression or anxiety. These two factors are unfavorable initial conditions for smooth learning.

Students may experience learning readiness that is not optimal, both due to physical factors and psychological factors so that the initial ability to think critically is in the low category.

Table 3. Data Recapitulation of Pretest and Posttest Students' Critical Thinking Skills

Counted Factors	Pretest	Posttest
The number of students	29	29
Lowest score	11,10	48,10
Highest score	51,90	88,90
Average	30,24	71,41
Ideal score	100	100
Standard deviation	9,64	10,60

Apart from being analyzed descriptively, the critical thinking ability of each student was analyzed for the magnitude of the increase through the N-Gain test. The magnitude of the increase is interpreted and accumulated for each category in percent form (Diagram 3). Based on Diagram 3, the data distribution of students' critical thinking skills improvement consists of; 3.45% of students belong to the low category, 79.31% of students belong to the medium category, 17.24% of students belong to the high category. So, most students experienced an increase in critical thinking skills in the moderate category. Thus, it can be said that the implication of phylogenetic worksheets is quite effective in increasing students' critical thinking skills in Spermatophyte classification material.

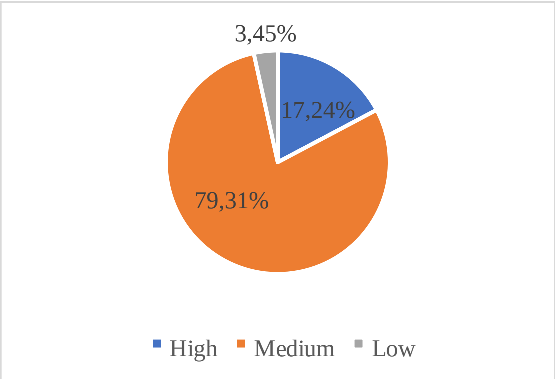

Diagram 3. Percentage of Increasing Students' Critical Thinking Skills

The magnitude of the increase in students' critical thinking skills is due to several factors, ie. the creation of many interactions, direct involvement to gain direct experience and explore knowledge independently. The implication of a phylogenetic worksheet to the classification of Spermatophyta learning creates a lot of interaction in learning activities. The interaction occurs with group members, with the teacher, reading texts or practice. Interaction among students with the focus on the learning processes and goals are crucial. Teacher should created plenty of opportunities for peer interaction to help learners discuss, evaluate, and reflect their learning experiences and performance while completing the tasks given during the class (Chorrojprasert, 2020). In order to ensure that the time and efforts spent on peer interaction is well invested and yield satisfactory results, students should be trained on how to effectively and constructively share information and debate on issues without causing conflicts among themselves.

This interaction is established because students are conditioned to do learning in small groups consisting of 4-5 people, so the interaction that occurs the first time is interaction between group members. Actually, both large group as well as small group can be utilized for optimal results in learning. Divided the students into large group is a convenient and oldest way to transmit large amount of information to large number of students. However, large group teaching is primarily teacher centered and if non interactive, can hamper the learning process (Saiyad et al., 2018). In contrass with large group, small group is more student centered and keeps the students in active mode (Saiyad et al., 2018). The facilitators and students together prepare the class and the students are encouraged to interact on along the learning. Strengths of small group teaching are flexibility, interaction, reflexivity, engagement. Based on the benefit of using the small group rather than the large group, choosing to use small groups is very appropriate in developing critical thinking skills in this research. This is evidenced by the increase in students' critical thinking skills as explained previously.

Supported by the results of interviews, students said that the learning is fun, one of which is being able to exchange ideas with other friend trough the discussion session. The discussion method can develop students' higher order thinking skills including critical thinking skills, because it can facilitate students to be able to actively participate in the learning process so that students can construct their own knowledge of new information, and also the students are able to solve the given problems (Hikmawati et al., 2021). According to Fatimah (Fatimah, 2019), the implication of the discussion can improve student learning outcomes and student activities. The same thing was also expressed by Senja & Nuryana (2016), the discussion increases students' activity, learning outcomes, and skills. In line with them, Hutahaean (2019) states that using the group discussion method can also increase students' learning motivation. Same as the result from other researchers that also suggests that the use of media-assisted discussion methods can improve students' ability to identify (Ariani, 2017). In addition to group members, this learning also facilitates students interacting with real specimens. The results of other studies show that the percentage of students' critical thinking skills in environment-based schools that use original specimens in their learning activities is higher than the critical thinking skills of students in multinational-based schools (Herawati, 2015). Students can also add a lot of information through direct observation. The more information students get, the higher the possibility of practicing their critical thinking skills.

Students are directly involved in learning activities through direct observation of specimens. With this direct involvement, it shows that students are active in experiencing and doing a learning process themselves (Aunurrahman, 2016). Direct observation activities will present direct experiences experienced by students. The direct experience experienced by students will be difficult to explain to other students who do not have the same experience as their friends (Arends, 2012). Information and experiences that are felt directly will be stored in long-term memory faster when the memory is made because of the many experiences that occur (Arends, 2012). Experience based learning becomes more meaningful when, (1) students are directly involved in the available learning experiences, (2) knowledge must be disclosed by students themselves, because it will be meaningful in the development of different new behaviors or knowledge, (3) and are committed to learning such as setting goals to be achieved and trying to reach predetermined goals (Johnson in Arends, 2012).

Exploring knowledge independently is also suspected as a factor in increasing students' critical thinking skills. Students are asked to compare the characteristics of the specimens themselves, then sort the specimens themselves based on their characteristics, then group the specimens that are considered to be closely related so that a phylogenetic tree is formed which is made and interpreted by themselves and this is in accordance with the practicum guidelines prepared by McCullough (McCullough et al., 2020). Supported by other research, that accustoming students to exploring knowledge independently can also improve critical thinking skills (Sari et al., 2019).

This research requires a more detailed analysis. Thus, analysis also needs to be done on each indicator of critical thinking skills. The score obtained by each student can also provide information related to the average percentage of students' critical thinking skills in each indicator (Diagram 4).

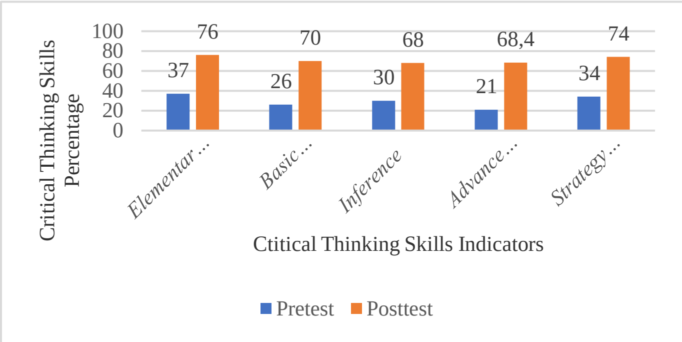

Diagram 4. Percentage of Pretest and Posttest Scores for Each Student's Critical Thinking Skills Indicators

Based on the results of data analysis for each student's pretest and posttest critical thinking questions, students' critical thinking skills were obtained for each indicator (Diagram 4). Based on data analysis for each of these indicators, there is no significant increase in students' critical thinking skills in any of the indicators. In this case, students' critical thinking skills in each indicator are evenly distributed in the medium category. When viewed from the highest increase, the highest increase in critical thinking skills occurred in the elementary clarification indicator, which was 0.62 (moderate). This is because these indicators only require the ability to interpret, determine questions and answer questions based on similarities and differences. Supported by the results of the interviews, students explained that the ability that was easiest to master was giving simple explanations. While the lowest increase in the Inference indicator is 0.54 (moderate). This ability is suspected because students have not been able to make simple, concise, and clear inferences. This is supported by the results of interviews, that students find it difficult to summarize general conclusions based on specific data and have difficulty interpreting some pictures. This is in accordance with research conducted by Pratiwi et al. (2022), that after using cladistic LKPD, the highest increase occurred in the simple explanation or elementary clarification indicator, which was 81% or in the very good category.

CONCLUSION

The application of phylogenetic worksheets to the Spermatophyta classification material is quite effective in increasing the tree thinking and critical thinking abilities of students with a majority in improving both abilities in the moderate category. The improvements in students' tree thinking skills are influenced by many factors like interest, seriousness, absorption, learning methods, and the language used in learning activities. Students with more chances to get a lot of interactions, direct involvement, and explore knowledge independently are able to improve their critical thinking skills more optimally. Students' responses to learning activities were also positive. Students find it helpful to understand the material faster. Learning to use phylogenetic trees on Spermatophyte classification material can be used as an alternative learning activity besides using the lecture method. The weakness of this study is that it does not test all sub indicators of critical thinking skills, and the other Higher Order Thinking Skill (HOTS) improvements. Based on tat, it is suggested for future researchers to focus on critical thinking skills on all indicators and test the implication of phylogenetic worksheets for the other HOTS improvements.

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