Applying phenetics approach to improve 21st century student plant literacy

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Abstract. The occurrence of plant blindness among students, then the plant literacy movement must be carried out intensively through learning in schools by applying phenetics approach. This study used a pre-experimental design pre-test and post-tests group. Pre-test about system thinking which is part of 21st century skills of critical thinking and problem solving regarding seed plants as aspects of 21st century plant literacy in high school students of class X MIPA in Bandung, conducted before phenetics learning. During learning, students are assigned to begin by identifying and selecting the characters of each taxon until reconstructing the phenogram. After phenetics learning, a post test was conducted. The results showed that there was an increase in 21st century plant literacy as much as 0.61 which included moderate categories and students could positively accept phenetics learning. Thus in addition to being a curriculum demand, phenetics also has the potential as a means to improve 21st century student plant literacy, but only a few aspects of system thinking can be developed. Further improvement is needed in phenetics learning, especially in selecting taxon and determining its characteristics.

1. Introduction
Because of the lack of students’ interest in studying plants and the low hour’s number of learning about plants in schools, the symptoms of plant blindness arise among students [1]. On the other hand Indonesia is known as a mega biodiversity country [2, 3, 4, 5], but ironically biodiversity in Indonesia has actually decreased [4, 6] caused by biological intrinsic factors, land constriction, over exploitation, natural factors, human activities and the introduction of new species [5, 6, 7]. Therefore the plant literacy movement must be intensively carried out, including in school.

As previous study [7] plant literacy used in this study refers to aspects of scientific literacy according to [8] which include competence and scientific knowledge. The competency in this study is one of the 21st century skills according to [9] and [10] namely system thinking which is part of critical thinking and problem solving, and the knowledge raised is the concept of seed plants. This 21st century skill is also a demand in the science curriculum [11] and Biology curriculum in high school [12]. Plant material itself is still considered difficult to learn by students and so far the learning has been dominated by teacher explanations [13]. One of the basic competencies that must be achieved by high school students in studying plantae is to present reports on the results of phenetics and phylogenetic observations and analyzes of plants and their role in life [12]. Phenetics is one approach of grouping living things using numerical algorithms from taxonomic units that are tested based on observed characters [14], so that it can be used to determine relationships between living things [15].
Research on the application of phenetics in biology learning has been done before, among them in increasing the mastery of the concept of plant diversity [16], in improving mastery of the concept of arthropods and student reasoning [17]. In applied biology phenetics is also used to trace relationships between plants in some species of the asteraceae [18], in some shiitake mushroom isolates [19], and in Anthurium species [20]. So far there has not been much revealed how the application of phenetics in improving 21st century plant literacy, especially about system thinking. Research on student system thinking has been carried out in physics and electrical engineering learning [21] in earth science learning [22, 23 and 24]. In biology learning, system thinking is examined specifically on ecology, metabolism and the circulatory system concepts [24, 25], in addition to cell biology concepts [26], while in seed plants concepts is still very limited, that is, among others related to students’ prior-knowledge [27].

2. Methods
The method used in this study was pre-experimental design pre-test and post-test group. Before phenetics learning is carried out, pre-test is done about system thinking which are part of 21st century skills critical thinking and problem solving regarding seed plants as aspects of 21st century plant literacy. During phenetics learning, students are assigned to begin by determining the taxa, identifying and selecting the characters of each taxon, calculating the level of similarity coefficients of taxa, compiling similarity coefficients in the form of matrices, followed by clustering until reconstructing the phenogram. After the phenetics learning was completed, a post test was conducted about system thinking.

Participants in this study were 31 high school students of class X in Bandung, West Java. The instruments used in this study are the pretest posttest questions of 21st century plant literacy in the form of system thinking aspects [8, 9, and 10], student worksheet about phenetics 1 and phenetics 2 and questionnaires on students’ responses to the phenetics application. The worksheet on phenetic students 1 emphasizes the grouping of seed plants based on the division of Gymnosperms and Angiosperms, while the worksheet of phenetics students 2 emphasizes the grouping of seed plants based on the class Dicots and Monocots. The system thinking indicators in this study refers to several criteria of [23], namely the ability to identify the components of a system, the ability to identify relationships among the system’s components and the ability to organize the systems’ components and processes within a framework of relationships. The increase of the ability of 21st century plant literacy (N-gain) is calculated from the pretest and posttest data following the rules of [28] and all values are categorized according to [29] rules.

3. Result and Discussion
From Table 1, it can be seen that the system thinking of students before the application of phenetics according to [29] includes very low categories, with an average value of 42.4, and after the application of phenetics including good categories with an average value of 77.6. At pre-test, the ability to determine plant kinship and determine the similarity of Dicot characters, are the lowest ability, as evidenced by the average pre-test value of 19.4. Before the application of phenetics, the highest system thinking ability of students was in the aspect of identifying the components of a system, namely the ability to determine Angiosperm characteristics and give examples of Monocot plants with an average value of 77.4 (Table 1).

After doing phenetics learning, determining the similarity of Spermatophyta characters is the highest ability of students, which reaches an average value of 96.8 (Table 1). Creating a plant classification concept map and determining the similarity of characters based on the phenogram are the lowest plant literacy abilities in the post test, which is the average value of each 60.0 (Table 1).

Overall there was an increase in plant literacy from before the application of phenetics until after the application of phenetics, with an average N-gain value of 0.61 (Table 2) which is in the moderate category according to [28] rules. The highest system thinking improvement is obtained in the aspects of organize the systems’ components, that is, the average N-gain value is 0.89 (Table 2).
The lowest improvement of system thinking is obtained in identifying the components of a system, that is, the average N-gain value is 0.33 (Table 2). This is likely to occur because from the beginning students have been able to identify the characters in the plant specimens, although in phenetics learning 1 and 2, the teacher determines the taxa and selects the character (Table 3 & 4), so there is no data for that aspect (-). If from the beginning the student themselves determine the taxa, then it is likely that students’ thinking systems will be different, but the quality of their inquiry are higher because it involves more students. This was also proposed by [30] that students should be involved in phenetics learning should taxonomists work in proving the hypothesis about the pattern of kinship before the classification is proposed. In this phenetics learning students only identify the characters from the taxa provided by the teacher, then determine the similarity of characters, compile the matrix and clustering, and finally compile the phenogram.

Table 1. The results of the pretest posttest of student plant literacy (system thinking) (N = 31)

| No. | System Thinking Aspects | Question Indicators                                      | Question No. | Pretest (%) | Posttest (%) | N-Gain (%) |
|-----|-------------------------|----------------------------------------------------------|--------------|-------------|--------------|------------|
| 1   | Identify the components of a system | Determine Gymnosperm characteristics                     | 1            | 74.2        | 87.1         | 0.33       |
|     | Identify the components of a system | Determine Angiosperm characteristics                     | 2            | 77.4        | 80.6         |            |
|     | Identify the components of a system | Give examples of Dicot plants                            | 3            | 74.2        | 87.1         |            |
|     | Identify the components of a system | Give examples of Monocot plants                          | 4            | 77.4        | 80.6         |            |
| 2   | Identify relationships among the system’s components | Determine the character of plant groups                  | 8            | 32.3        | 83.9         |            |
|     | Identify relationships among the system’s components | Determine the similarity of Dicot characters              | 7            | 19.4        | 61.3         |            |
|     | Identify relationships among the system’s components | Determine the similarity of Monocot characters            | 9            | 22.6        | 67.7         |            |
|     | Identify relationships among the system’s components | Determine the similarity of Spermatophyta characters      | 10           | 41.9        | 96.8         |            |
|     | Identify relationships among the system’s components | Determine plants with far kinship                        | 5            | 22.6        | 80.6         |            |
|     | Identify relationships among the system’s components | Determine plants with close kinship                      | 13           | 22.6        | 64.5         |            |
|     | Identify relationships among the system’s components | Determine plants kinship                                 | 6            | 19.4        | 64.5         |            |
|     | Identify relationships among the system’s components | Make a concepts map of plants classification              | E1           | 26.0        | 60.0         |            |
|     | Identify relationships among the system’s components | Determine the similarity of plants based on phenogram    | E2           | 26.0        | 60.0         |            |
| 3   | Organize the systems’ components | Explain the impact of classification changes              | 11           | 41.9        | 93.5         |            |

Average: 42.4 | 77.6

- : No data

Table 2. Recapitulation of mastery of student plant literacy (System Thinking) (N = 31)

| No. | System Thinking Aspects | Pretest | Worksheet | Posttest | N-Gain |
|-----|-------------------------|---------|-----------|----------|--------|
|     |                         |         | 1 | 2 |     |   |
| 1   | Identify the components of a system | 75.8 | - | - | 83.9 | 0.33 |
| 2   | Identify relationships among the system’s components | 25.8 | 90.9 | 91.2 | 72.4 | 0.63 |
| 3   | Organize the systems’ components | 41.9 | 60.8 | 65.0 | 93.5 | 0.89 |
|     | Average                 | 42.4 | 81.6 | 82.4 | 77.6 | 0.61 |

- : No data

Student performance since identifying characters until compiling a phenogram has been included very well, both on phenetics 1 and on phenetics 2 (Table 3 & 4). Nonetheless, this result is still in the beginner/initiation level, because the reliability of the phenogram depends on the quality and quantity of the previous stage, such as the number of taxa used, number of characters used, and accuracy of observations on the character and sequence of the steps taken [30]. The more taxon and character used the reliability level of the phenogram can higher. While the taxon used in phenetics 1 only amount 4, namely pine, *Gnetum gnemon*, *Canna hibrida* and mango. The selected characters also only have 6,
namely have leaf vein, covered seeds, woody stems, have strobilus, have soft stems and have fruit, all of which are determined by the teacher. Likewise in phenetics 2, there is only one additional specimen compared to phenetics 1, namely corn and its additional character are have seeds and leaf bones. For future phenetics applications, preferably the number of specimens is added and the character is determined by the student, so students can prove more accurately the classification of plants based on the phenogram.

In answering questions on worksheet, the ability of students in the identify aspect of relationships among the system components, including good and very good categories (Table 3 & 4), but in the aspect of organizing the systems' components are still classified as low and very low (Table 3 & 4). The low ability of students in organizing the systems aspects 'components, especially in answering questions on worksheets, is likely due to students' inaccuracies in classifying plants. For example students are asked to classify Dicot plants; most students only write one example of a specimen that includes Dicot, not listing all the plants including Dicot. In addition, students are also still wrong in identifying the characteristics of Monocot plants, namely leaf bones. The disadvantages in this study also lie in the lack of evenly distributed aspects of system thinking on the questions, that is, the problem that organizes the systems' components is only one question, while the identify relationship among the system components is 9 questions (Table 1).

**Table 3.** Value of student performance and answer questions on phenetics worksheet 1

| No. | System Thinking Aspects | Performance Indicators | Value (%) | Questions Indicators | Value (%) |
|-----|-------------------------|------------------------|-----------|----------------------|-----------|
| 1   | Identify the components of a system | Determine the taxa | - | Describe close kinship of plants | 83 |
|     |                          | Character identification & selection | - |                          | - |
| 2   | Identify relationships among the system’s components | Determine the similarity of taxa | 100 | Determine plants with close kinship | 94 |
|     |                          | Compile the matrices of similarity coefficients | 100 | Determine plants with the lowest coefficient | 83 |
|     |                          | Compile the clustering | 98 | Describe far kinship of plants | 81 |
|     |                          |                          |     | Determine plants with far kinship | 97 |
|     |                          |                          |     | Determine characters that influence coefficient and kinship | 82 |
| 3   | Organize the systems’ components | Construct the phenogram | 98 | Grouping Gymnosperms based on phenogram | 41 |
|     |                          |                          |     | Grouping Angiosperms based on phenogram | 53 |
|     |                          |                          |     | Grouping Spermatophyta based on phenogram | 51 |

- : No data

**Table 4.** Value of student performance and answer questions on phenetic worksheet 2

| No. | System Thinking Aspects | Performance Indicators | Value (%) | Questions Indicators | Value (%) |
|-----|-------------------------|------------------------|-----------|----------------------|-----------|
| 1   | Identify the components of a system | Determine the taxa | - | Determine the pairs of plants with the highest coefficient | 86 |
|     |                          | Character identification & selection | - |                          | - |
| 2   | Identify relationships among the system’s components | Determine the similarity of taxa | 100 | Determine the pairs of plants with the lowest coefficient | 83 |
|     |                          | Compile the matrices of similarity coefficients | 100 | Determine characters that influence coefficient and kinship | 82 |
|     |                          | Compile the clustering | 96 |                          | - |
The results of this study indicate that the applying of phenetics approach can improve 21st century plant literacy in students, especially in system thinking in the moderate category (Table 2), besides it can be used to improve the mastery of the concept of plant diversity in students [16] and improve mastery of the concept of arthropods and student reasoning [17]. In addition, the application of phenetics approach can also be used to trace the relationships between plants and other living things in order to find superior characters [18, 19, 20]. From the questionnaire, most of the students stated that the material (specimen) and steps of phenetics practicum guide were well implemented and were useful in studying plant relationships. In this study, the application of phenetics in the concept of seed plants is limited to developing only three student thinking systems criteria proposed by [23], namely identify the components of a system, identify relationships among the system’s components and organize the systems’ components. Other system thinking criteria cannot be developed because of the limited characteristics of the material being studied, unlike ecological and metabolic material which is loaded with processes and interdependence between system components [24, 31].

4. Conclusion
Applying phenetics approach can improve 21st century plant literacy in students, especially in system thinking, as much as 0.61 which is in the moderate category and students could positively accept phenetics approach. Thus in addition to being a curriculum demand, phenetics also has the potential as a means to improve 21st century student plant literacy, but only a few aspects of system thinking can be developed. Further improvement is needed in phenetics approach, especially in selecting taxon and determining its characteristics.

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