Research Article

Numerical Taxonomy in School: Sustainability in Biodiversity Learning

Topik Hidayat

Department of Biology Education, Universitas Pendidikan Indonesia, Jl. Dr. Setiabudi No. 229, Bandung 40154, Indonesia

ORCID
Topik Hidayat: https://orcid.org/0000-0002-4589-8059

Abstract.
The younger generations of Indonesia are usually uninterested in studying biodiversity because the teaching process at schools tends to use the one-way lecture method, and the students tend to memorize. This paper discusses the implementation of numerical taxonomy into learning about biodiversity, which is likely more sustainable than existing teaching methods. Numerical taxonomy is a grouping system that consists of two approaches, phenetics and cladistics. The implementation of numerical taxonomy in biodiversity learning promoted students to be active, participative, and engaged in hands-on experience as required by sustainability education. Numerical taxonomy in biodiversity learning is characterized by student-centered learning, a lot of hands-on activities, exploring the 21st-century skill (4Cs), and imitating. In addition, it demonstrated quite good concept mastery of students and positive responses from the students. The results suggested that feeling fun and excited was a further simple meaning of sustainability itself. There is a strong connection between numerical taxonomy, 21st-century skills, and education for sustainable education.

Keywords: numerical taxonomy, biodiversity, phenetics, cladistics

Corresponding Author: Topik Hidayat; email: topikhidayat@upi.edu

Published: 3 April 2024

Publishing services provided by Knowledge E

Selection and Peer-review under the responsibility of the ICMScE Conference Committee.

1. INTRODUCTION

Even though it only occupies 1.3% of the world's land surface, Indonesia is one of the richest countries in the world in terms of biodiversity. Indonesia has around 17,000 islands where there are unique ecosystems containing a large number of diverse species. Indonesia is one of 17 countries with the nickname "Megabiodiversity", two of the world's 25 biodiversity hotspots, one of the 18 "Global 200" ecoregions of the World Wildlife Fund, and one of the world's 24 endemic bird areas [1].

Furthermore, Indonesia has about 12% of the world's mammals (515 species), placing it second only to Brazil. About 16% of the world's reptiles (781 species) and 35 primate species make Indonesia ranked fourth in the world. In addition, 17% of the total bird species (1,592 species) and 270 amphibian species rank Indonesia fifth and sixth in the world, respectively. For plant diversity, Indonesia has 10% of the world's flowering plant species (approximately 35,000 plant species) and ranks as one of the world's centers of agro-biodiversity in the form of plant cultivars.

One of the problems related to the status or position of Indonesia's great biodiversity is insufficient human resources to manage it. Not many people, especially the young generation, in Indonesia are interested in pursuing the field of biodiversity. The root of this problem most likely comes from the school. In fact, biodiversity learning in the classroom is far from sustainable [2]. Teachers tend to use the one way lecture method in teaching (teacher center), and the students tend to memorize, without understanding it, so they are unable to apply theories and concepts to solving real problems. Another thing is the teaching and learning process that is carried out is rigid which makes students feel bored.

2. METHOD

This paper offers a process of learning about biodiversity through the implementation of numerical taxonomy in the classroom, which is more likely sustainable than existing one. Results of the study that have been carried out will be reviewed and be linked to current issues regarding sustainability education and the 21st century skills.

3. RESULT AND DISCUSSION

3.1. Sustainability in Learning

In etymological context, sustainable means something that is able to be sustained, i.e, something that is "bearable" and "capable of being continued at a certain level". Then, sustainability can perhaps be seen as the processes by which something is kept at a certain level. Thus, in a learning context, sustainability refers to the learning environment that makes students feel passionate about learning, so that they want to keep on pursuing the field of their interests in the next level. To facilitate all of this, it is required a shift mindset of teachers to provide learning methods towards active, participative, and experiential that engage students and make a real difference to their understanding, thinking and ability to act [3].

Teachers play a significant role in enabling students to develop values, skills, and knowledge required to create equitable, cooperative & sustainable societies. Changing the way students think and act as individuals & societies is the aim of education for sustainable development [4]. Those changes will be enhanced by fully involving critical thinking, creative and innovative, communication, and collaboration in every single learning process.

3.2. Numerical Taxonomy as a Solution

Numerical taxonomy is a system of grouping living things using a numerical algorithm from taxonomic units that are tested on the basis of the observed characters. The numerical classification is divided into two approaches, namely phenetics and cladistics (Figure 1). Phenetics, if the grouping is done based on overall similarity, and cladistics, if the grouping is based on the evolutionary history of the taxa being tested.

The steps to carry out a phonetics analysis include specimen selection, character and character state selection (informative, objective, and specific), characterization, similarity index (SI) calculation, clustering, phenogram reconstruction. Similarity index is calculated based on the number of similarity between two specimens per total character state observed. Similarity index must be ranged 0 – 1. Cladistics analysis consists of steps: taxon selection, character and character state selection, characterization, calculating evolutionary character change compared to outgroup, sequencing the number of character state changes from smallest to largest, reconstructing of cladogram, and putting the shared derived character state on the branch.

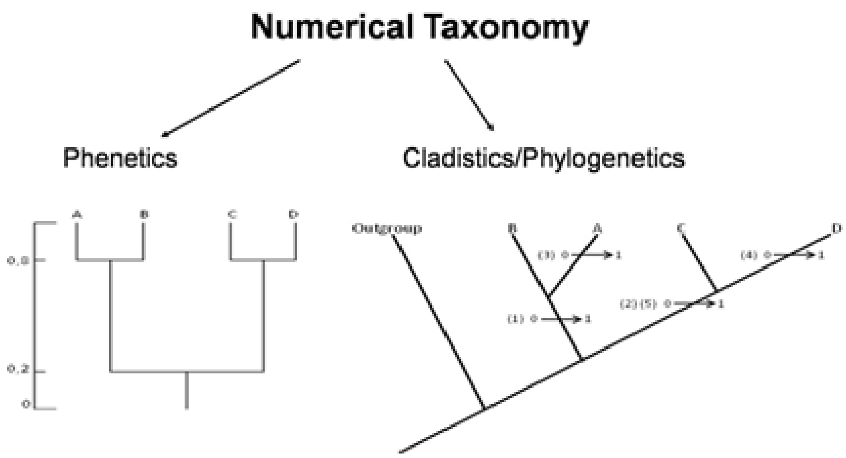


Figure 1: Two approaches of numerical taxonomy.

In implementation, teachers and students may conduct simple analysis involving a few specimens and character states. For example, we select four specimens (A,B,C,D) and five character states (1,2,3,4,5), then characterize them by scoring "1", if present, and "0", if absent (see Figure 2 for detail). Simulation of phenetics and cladistics analysis using data available in Figure 2 are continued in Figure 3 and Figure 4, respectively.

	1	2	3	4	5
A	1	0	1	0	0
B	1	0	0	0	0
C	0	1	0	0	1
D	0	1	0	1	1

Figure 2: Characterization (taxa vs. character state).

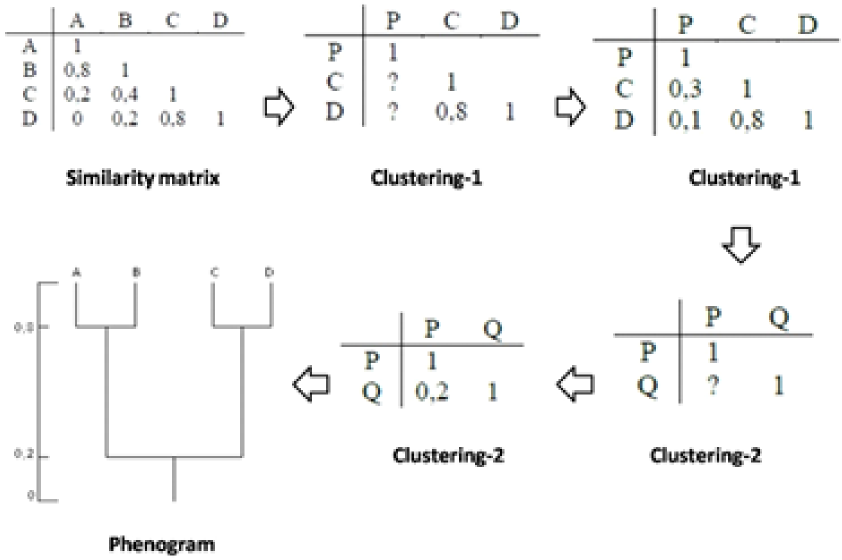
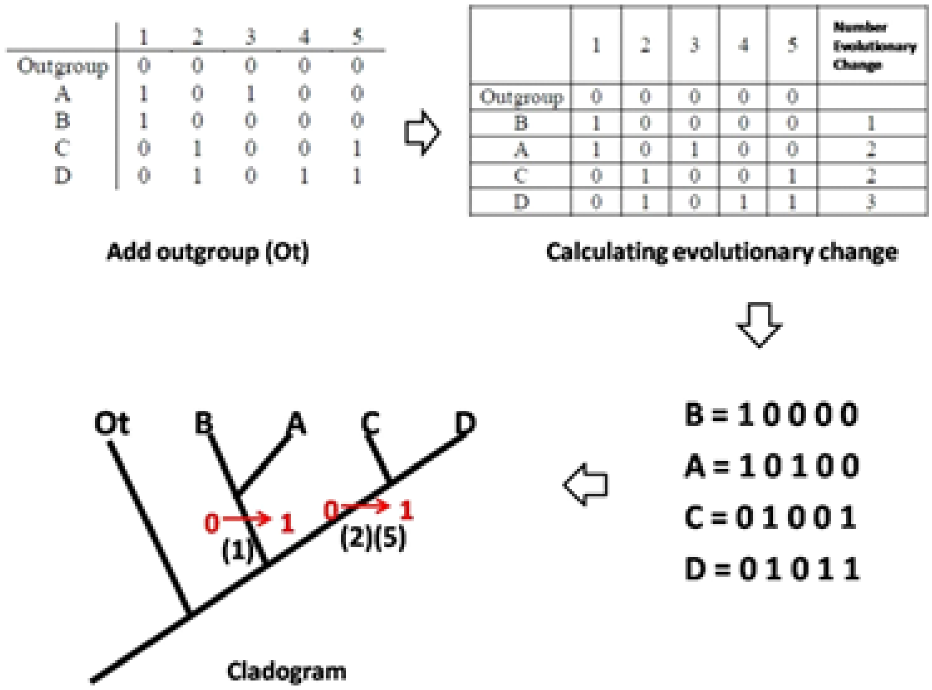


Figure 3: Step by step of phenetics analysis.

These learning activities promote students to be active, participative, and hands on experience about biodiversity [5] as required by sustainability education. Further analysis by conducting numerical taxonomy makes students able to find or create their own knowledge (inquiry) on differences of plant group, for example, Gymnosperm and Angiosperm, or Dicot and Monocot, as described in Figure 5. Without memorizing, but they understand it. Teachers and/or students just select specimens (plants, animals, even microbes) that are desired to be examined.

In contrast with phenogram, cladogram needs special skill of reading and interpreting, that is called "Tree-Thinking". Tree-Thinking is described as the ability to conceptualize evolutionary relationships [6], and is a key component of twenty-first century science literacy [7]. Tree-Thinking skill indicators include at least the origin, clade (monophyletic group), evolution characters, most recent common ancestor (MRCA) [8].

According to cladogram in Figure 4, it is simply can be interpreted, for example, that: (1) Two specimens AB in one side and CD in the other side are monophyletic group



	1	2	3	4	5
Outgroup	0	0	0	0	0
A	1	0	1	0	0
B	1	0	0	0	0
C	0	1	0	0	1
D	0	1	0	1	1

	1	2	3	4	5	Number Evolutionary Change
Outgroup	0	0	0	0	0	
B	1	0	0	0	0	1
A	1	0	1	0	0	2
C	0	1	0	0	1	2
D	0	1	0	1	1	3

Figure 4: Step by step of cladistics analysis.

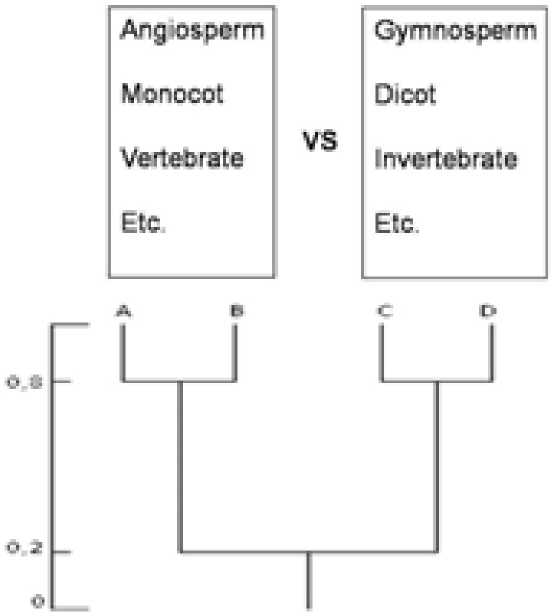


Figure 5: A phenogram. A and B are representative specimens for one group, and the other for C and D.

(Clade) respectively; (2) A and B share character state 1, and character 2 and 5 are synapomorphy for C and D; (3) A and B are more primitive group than C and D; and (4) Figure 6 shows the MRCA among the specimens examined. For example, it may be read that MRCA 2 includes all specimens, MRCA 4 for C and D, and so on.

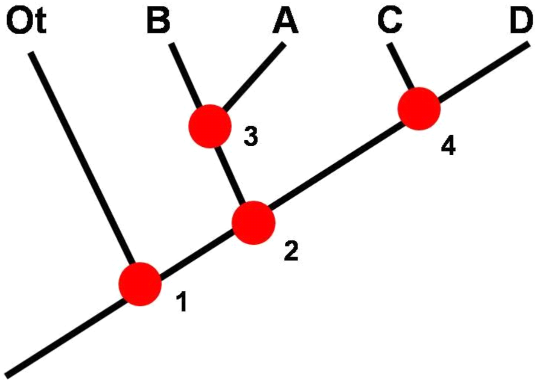


Figure 6: MRCA on cladogram that is indicated by red circle.

3.3. Numerical Taxonomy Versus 21st Century Skills

There is a link among education for sustainable education (ESD), numerical taxonomy, and 21st century skill, where the 21st century skill is a bridge that connects numerical taxonomy and ESD. On the basis of our research, every single step of both phenetics and cladistics analysis can be mapped to the 21st century skill which is critical thinking (CRI), creative and innovative (CRE and INNOV), communication (COMM), and collaboration (COLL) (often called as 4Cs) [9]. Table 1 describes in detail about this.

Table 1: Numerical taxonomy vs. 4cs.

No.	**Phenetics**	**4Cs**				**Cladistics**	**No.**
		CRI	**CRE & INNOV**	**COMM**	**COLL**		
1.	Taxon selection	-	-	-	-	Taxon selection	.1
2.	Character state selection	☒	☒			Character state selection	.2
3.	Characterization	☒				Characterization	.3
4.	Similarity Index	-	-	-	-	Evolution changes	.4
5.	Clustering	☒				Sequence of evolution changes	.5
6.	Phenogram reconstruction	☒	☒			Cladogram reconstruction	.6
		☒				Plotting synapomorph	.7
7.	Report and Presentation			☒	☒	Report and Presentation	.8

Concept mastery of students and their responses were collected and analysed in relation with the implementation of numerical taxonomy in biodiversity learning process. As seen in Figure 7, students' concept mastery was quite satisfying, and students were feeling fun and excited (Figure 8). It is simply suggested that sustainability refers to when students feel fun and excited in their learning.

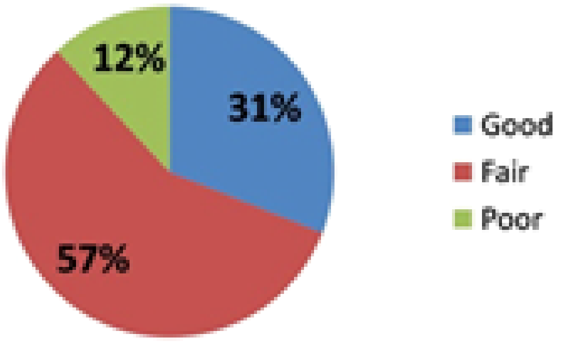


Figure 7: Concept mastery of students after implementation of numerical taxonomy (total responden= 900).

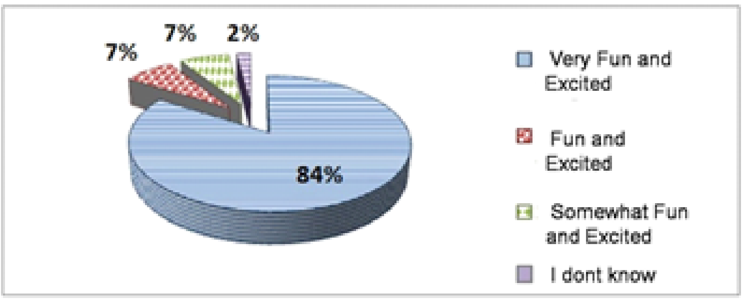


Figure 8: Response of students related to numerical taxonomy implementation (total responden= 900).

3.4. Imitating in Biodiversity Learning

Social learning theory, proposed by Albert Bandura in 1977, emphasizes the importance of observing, modelling, and imitating the behaviors, attitudes, and emotional reactions of others [10]. Social learning theory considers how both environmental and cognitive factors interact to influence human learning and behavior [11]. Individuals that are observed are called models. In the same manner, we can apply this theory in biodiversity class. Students try to imitate what scientists (as a model) in the field of biodiversity, namely taxonomists and biosystematics, do their job, which routinely perform numerical taxonomy. This will leave an impression and traces of knowledge of students at the next level in the future.

4. CONCLUSION

In the end, it is concluded that numerical taxonomy in biodiversity learning is characterized by student center based learning, a lot of hands-on activities, exploring the 21st century skill (4Cs), and imitating. Numerical taxonomy, 21st century skill, and ESD are connected to each other in biodiversity learning.

ACKNOWLEDGMENTS

Some parts of this research were funded by UPI Post Graduate School grants for which we are very grateful.

References

[1] Corson C. Shifting environmental governance in a neoliberal world: US aid for conservation. Antipode. 2010;42(3):576–602.

[2] Yli-Panula E, Jeronen E, Lemmetty P, Pauna A. Teaching methods in biology promoting biodiversity education. Sustainability (Basel). 2018;10(10):1–18.

[3] Ilbury DT. Are we learning to change? Mapping global progress in education for sustainable development in the lead up to 'rio plus 20,'. Glob Environ Res. 2010;14:101–7.

[4] Wan G, Gut DM. Bringing schools into the 21st century. New York: Springer; 2011.https://doi.org/10.1007/978-94-007-0268-4.

[5] Oktaviani F, Hidayat T. Profil keterampilan berkomunikasi siswa sma menggunakan metode fenetik dalam pembelajaran klasifikasi arthropoda. Jurnal Pengajaran MIPA. 2015;15(1):13–24.

[6] Meisel RP. Teaching tree-thinking to undergraduate biology students. Evolution (N Y). 2010 Jul;3(4):621–8.

[7] Novick LR, Catley KM. Teaching tree thinking in an upper level organismal biology course: testing the effectiveness of a multifaceted curriculum. J Biol Educ. 2018;52(1):66–78.

[8] Novick LR, Catley KM. Reasoning about evolution's grand patterns: college students' understanding of the tree of life. Am Educ Res J. 2013;50(1):138–77.

[9] Voogt J, Roblin NP. A comparative analysis of international frameworks for 21 st century competencies: implications for national curriculum policies. J Curric Stud. 2012;44(3):299–321.

[10] Edinyang SD. The significance of social learning theories in the teaching of social studies education. International Journal of Sociology and Anthropology Research. 2016;2(1):40–5.

[11] Nielsen M. Copying actions and copying outcomes: social learning through the second year. Dev Psychol. 2006 May;42(3):555–65.