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ANALYSIS OF CITIZEN SCIENCE-BASED FLOWERING PLANT DIVERSITY WORKSHEET DEVELOPMENT TO IMPROVE STUDENTS' CRITICAL THINKING ABILITY

Nissa Rachmawati[1], Topik Hidayat[2], Bambang Supriatno[3]
[1]Master Programme of Biology Education, Universitas Pendidikan Indonesia, Indonesia
[2]Department of Biology Education, Universitas Pendidikan Indonesia, Indonesia
[3]Department of Biology Education, Universitas Pendidikan Indonesia, Indonesia

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ABSTRACT (9)
The purpose of this study was to assess the feasibility of the developed Citizen Science-Based Flowering Plant Diversity Worksheet as well as the enhancement of students' critical thinking abilities. This was a pre-experiment with a pretest-posttest design with one group. Validator employed a four-scale validation sheet to assess the feasibility of the Citizen Science-Based Flowering Plant Diversity Worksheet based on competency, practical, knowledge construction, and the appearance of critical thinking ability. Five critical thinking ability indicators were tested: interpretation, analysis, explanation, evaluation, and inference. These indications were tested in 104 10th grade students through a critical thinking ability test before and after studying with the Citizen Science-Based Flowering Plant Diversity worksheet. Descriptive statistics were used to analyze the data. The Citizen Science-Based Flowering Plant Diversity Worksheet was found feasible (95.12%) and students' critical thinking abilities increased moderately (N-Gain = 0.56). The most notable development in critical thinking ability was in interpretation ability, while inference ability improved the least. As a result, the Citizen Science-Based Flowering Plant Diversity Worksheet may be inferred to be quite effective in improving students' critical thinking abilities.

Corresponding Author:
Topik Hidayat,
Department of Biology Education, Universitas Pendidikan Indonesia
Jalan Dr. Setiabudhi 229 Sukasari, Bandung 40154, Indonesia
Email: topikhidayat@upi.edu

1. INTRODUCTION

According to the Convention on Biological Diversity, the loss of biodiversity will have an effect on all elements of the earth and is currently a severe problem for the entire planet. In order to sustainably reap the benefits of biodiversity, it is imperative that it be taken into account in all levels of decision-making (Mrema, 2021). Students will experience decision-making in the future when they integrate into the community. Consequently, the foundation for the growth of a society that is engaged and responsible is education (Schneiderhan-Opel & Bogner, 2020).

Digital technology has been increasingly incorporated into the educational system during the last few decades. Facing this challenge requires competencies that can develop effective cognitive, social and emotional skills known as digital literacy competencies (Silber-Varod et al., 2019). A number of competencies that are important for learning in a digital environment include complex problem solving, communication, collaboration, creativity, and critical thinking (Hwang et al., 2015). To contribute positively to community activities and take part in biodiversity decision-making, one needs critical thinking abilities that incorporate problem-solving and the capacity for argumentation (Zanata & Santovito, 2020).

In Indonesian education, learning about biodiversity is not something new. Student-centered biodiversity learning activities such as practical work have existed since 1994 (Rachmawati et al., 2021). Worksheets are typically used in conjunction with practical activities. The biodiversity worksheet that used in Indonesia contains activities to identify living things and categorize them into various levels such as genes, species and ecosystems. This knowledge and identification of species is important for students, especially in everyday life, for example, to recognize poisonous plants and animals, dangerous invasive species, where plants and animals live, reproduce,

and grow and their relationship with the environment (Lindemann-Matthies, 2005). However, the findings of the existing biodiversity worksheet analysis did not fully train students' critical thinking skills. In addition, the species identification data obtained from practical activities are only useful for students and less useful for others (Rachmawati et al., 2021).

Practical work that is integrated with Citizen Science is thought to be capable of developing critical thinking skills and benefiting others. Citizen science is defined as community involvement in a scientific project involving professional scientists and producing accurate data and information that can be used by all parties—scientists, decision-makers, and the community itself (McKinley et al., 2017; Miller-Rushing et al., 2012). Some indicators of critical thinking skills according to Facione, (2015) such as the ability to interpret, analyze, explain, evaluate and inference can be trained at several stages of scientific investigation in citizen science activities, including defining questions/issues, developing explanations, analyzing samples, interpreting data, and making conclusions (Bonney et al., 2009). By utilizing digital technology, data from the identification of biodiversity can also be widely shared through Citizen Science activities.

Aripin & Hidayat, (2020) conducted previous research on Citizen Science activities in Indonesia at the university level to monitor butterfly diversity. The challenge is that for some schools in urban areas, butterflies are difficult to find, so other living things that are easier to observe, such as plants, are required. Langager (2019), on the other hand, conducted a study integrating Citizen Science in the topic of plant diversity at the high school level, with critical thinking skills as the learning outcomes measured. However, this activity is completed in 8 months and is not appropriate for the Indonesian learning curriculum. In order to comply with the Indonesian curriculum, it is necessary to create Citizen Science-based flower plant diversity practical activities in addition to the worksheet, which are expected to improve students' critical thinking abilities. As a result, the purpose of this study is to assess the feasibility of the developed Citizen Science-based flowering plant diversity worksheet as well as the improvement of students' critical thinking skills before and after learning with the Citizen Science-based flowering plant diversity worksheet.

2. RESEARCH METHOD

This study used a pre-experimental design with one group pretest-posttest. Participants in this study included 104 of 10th grade high school students from Sumedang, West Java. The validation sheet and critical thinking ability test questions were used in this study to determine the feasibility of the Citizen Science-based flowering plant diversity worksheet. Conceptual aspects, procedural aspects, knowledge construction aspects (Novak & Gowin, 1984), and appearance aspects of critical thinking ability are the four aspects evaluated to determine the feasibility of the worksheet. Critical thinking ability test questions are made in the form of essays with five indicators of critical thinking skills used referring to Facione (1989): interpretation, analysis, explanation, evaluation and inference. The worksheet validation results are converted into percentages and categorized. Meanwhile, SPSS was used to test the validity and reliability of the critical thinking ability test. The validity score was > 0.306 and the reliability score was 0.93, indicating that the critical thinking ability test used was valid and reliable (Arikunto, 2013). Before and after learning, critical thinking ability tests are administered using a citizen science-based practical guide on flowering plant diversity that has been validated by expert lecturers.

3. RESULT AND DISCUSSION

This research produces a biodiversity learning product that has been adapted to the needs of the Indonesian curriculum, namely a Citizen Science-based Flowering Plants Diversity Worksheet. The essence of Citizen Science activities is the participation of students in scientific work conducted by experts/communities, in this case through citizen science projects on the iNaturalist platform. The data collected by students is first combined in the Flowering Plants in the Schoolyard mini project so that it can go through the inspection stage before being submitted to a larger project, namely Flowering Plants of Indonesia. According to the findings of a study conducted on 104 high school students in Sumedang, researchers examined the impact of citizen science-based flowering plant diversity worksheets on students' critical thinking skills and activity processes during learning.

Student activities in using citizen science worksheets are adapted to the stages of scientific investigation according to Bonney et al., (2009) including defining questions, collecting information, developing explanations, designing data collection steps, collecting and analyzing samples, analyzing and interpreting data and drawing conclusions. The elements of the citizen science-based flowering plant diversity worksheet are separated into four sections: introduction, training, practical activity, and guide. Figure 1 depicts the display of citizen science-based worksheets.

Figure 1. Four main sections of the Citizen Science-based flowering plant diversity worksheet.

After the citizen science-based worksheets are generated, expert lecturers conduct validation testing. Validation is examined from various perspectives, including conceptual, procedural, knowledge generation, and critical thinking skills application. Table 1 shows the findings of the validation analysis.

Table 1. Result of Validation Analysis

Aspect	Indicator	Max Score	Score	Aspect	Indicator	Max Score	Score
Conceptual Aspects	Content suitability with basic competence	4	4	Knowledge Construction	Quality of Title/ Aim/ Focus Question	4	4
	Competency suitability with basic competence	4	4		Quality of Identifiable Object/ events	4	3.5
	Activities suitability with students' cognitive level	4	**4**		Quality of Concepts and principles	4	3.5
	Percentage		**100%**		Quality of Data recording and transformation	4	3.5
Procedural Aspect	Title suitability with practical activities	4	4		Quality of Knowledge klaim	4	3.5
	Objective suitability with practical steps	4	4		**Percentage**		**90%**
	Ease to obtain tools and materials	4	4	Application of critical thinking	Appearance of interpretation ability	4	4
	Clarity of practical steps	4	3.5		Appearance of analysis ability	4	4
	Ease of doing practical steps	4	3.5		Appearance of explanation ability	4	4
	Suitability of objects/ events appearance	4	3		Appearance of evaluation ability	4	4
	Ease of observing object/ events appearance	4	3		Appearance of inference ability	4	4
	Percentage		**90.5%**		**Percentage**		**100%**

The pupils' critical thinking abilities were assessed through the use of 15 questions based on critical thinking indicators. The indications are interpretation, analysis, explanation, evaluation, and inference. Table 2 shows the results of critical thinking abilities after learning with citizen science-based worksheets. The improvement in results from pretest to posttest demonstrates the benefit of using Citizen Science-based flowering plant diversity worksheets in learning. Table 3 displays pre- and post-test data on students' critical thinking abilities

Table 2. The Results of Students' Critical Thinking Abilities

No.	Indicator	Max Score	Average	Percentage	Category
1.	Interpretation	3	2.52	83.87%	Very Good
2.	Analysis	3	2.59	86.43%	Very Good
3.	Explanation	3	2.18	72.76%	Good
4.	Evaluation	3	2.14	71.36%	Good
5.	Inference	3	2.14	71.26%	Good

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

No.	Test	Number of Participants	Average	Category	N-Gain	N-Gain Category
1.	Pretest	104	48.13	Acceptable	0.56	Fair/Moderate
2.	Postest	104	77.07	Good		

Based on the data in Table 1, the average percentage of the four aspects is 95.12%. According to the worksheet feasibility categorization (Nugroho & Subiyantoro, 2017), the worksheet with a percentage of $81 \leq n < 100$ represents a very good qualification and feasibility. On the conceptual aspect, the activities that can be performed in the Citizen Science worksheet involve students to identify plants in the schoolyard and then submit the data on the iNaturalist platform. From the data that has been collected, students are required to analyze whether there is gene, species and ecosystem plant diversity level in the school area. After that, students are required to analyze problems related to plant diversity that may occur in schools and their solutions. This is in accordance with basic competence 3.2 namely "Analyzing various levels of biodiversity in Indonesia, their threats and conservation" and basic competence 4.2, namely "Presenting the results of biodiversity observation at various levels in Indonesia and their conservation efforts" (Peraturan Menteri Pendidikan Dan Kebudayaan Indonesia, 2018).

According to the data in Tables 2 and 3, the highest critical thinking abilities of pupils are interpretation ability, analytical ability, explanation ability, assessment ability, and lastly inference ability. Students' critical thinking abilities have also improved. This is evidenced by the fact that the average posttest value is higher than the pretest value. The posttest average for pupils' critical thinking skills is in the good category (Arikunto, 2013). The N-gain test results revealed that the average increase in students' critical thinking ability is 0.56, which can be considered fair or moderate (Hake, 1999). The highest critical thinking ability of students is owned by the interpretation ability (86.43%). Interpretation ability refers to the ability of students to understand and express the meaning of situations, data, criteria or procedures (Facione, 1989). In this study, the form of interpretation ability on critical thinking abilities is a question about grouping into levels of biodiversity and classification into Magnoliopsida/Liliopsida groupings based on plant traits. According to (Bonney et al., 2016), one of the characteristics that may be developed and quantified after participating in citizen scientific activities is the ability to interpret. In line with Kermish-Allen et al., (2019), although being deployed in a short period of time, citizen science weather blur activities have a considerable impact on students' capacity to understand. One of the reasons for the high interpretive ability in this study is that when citizen science activities take place, most students do interpreting activities such as defining focus questions, gathering information, interpreting graphs, classifying into Magnoliopsida or Liliopsida, and categorizing into levels of biodiversity. The more frequently it is done, the more students are trained.

Inference ability, on the other hand, is the lowest capacity after learning (71.26%). Inference capacity is defined by Facione, (2015) as the ability to identify and secure the pieces required to reach plausible conclusions. Making alternatives, such as formulating plans to collect data, or when faced with an issue, a student can construct many ways to solve it, are examples of sub inference abilities. Students' inference ability on critical thinking questions provides answers to address the weakness of plant data and plant diversity issues. One possible explanation for the poor increase in inference ability is when the ability to give answers to data weakness/problems is only educated in a limited scope, such as the school setting. Meanwhile, critical thinking requires the ability to give solutions to larger-scale challenges. Many pupils merely offer the most broad and limited solutions. Despite receiving the lowest score of the four indicators, the inference ability still grew in the moderate category.

A Citizen Science-based worksheet on the diversity of flowering plants might help students enhance their critical thinking skills. Various citizen science projects in other biological variety concepts such as animal, fungi, or even protist can be developed for further research, but should evaluate the suitability with the current curriculum and school needs.

4. CONCLUSION

Based on the findings of the analysis, it is possible to conclude that the use of Citizen Science-based worksheets after validation tests by expert lecturers was obtained in a variety aspect, including 100% for the conceptual aspect, 90.5% for the procedural aspect, 90% for knowledge construction, and 100% for the application of critical thinking ability. This means that the Citizen Science-based worksheet is feasible to use in flowering plant diversity concept. Furthermore, there is an improvement in critical thinking capacity. This is demonstrated by obtaining an N-Gain value of 0.56 in the moderate/fair category. As a result, the construction of the Citizen Science-Based Worksheet is quite effective in enhancing high school students' critical thinking abilities in interpretation, analysis, explanation, evaluation, and inference.

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