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Citizen science project's contributions to species literacy for pre-service biology teacher

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ABSTRACT

This study aims to describe the contribution of the Citizen Science Project (CSP) program to the species literacy of pre-service biology teachers. Using a quasi-experimental method with a Citizen Science (CS) approach, this study involved 82 participants from two campuses who were recruited voluntarily for two different projects. A total of 68 participants were involved in Project I (monitoring of insect pollinators of mango (*Mangifera indica*) inflorescence) and 14 participants were involved in Project II (monitoring of butterflies in citrus (*Citrus amblycarpa*) plantations). A species literacy test and a questionnaire were used as data collection instruments. The species literacy test consists of 14 items of species identification questions for Project I and 12 items of species identification questions for Project II. The questionnaire was used to determine the perception and evaluate the learning outcome (LO) of the CSP program. The data were analyzed statistically and described according to the research findings. The results showed that species literacy in pre-service biology teachers improved in the moderate category. Most participants perceived that the CSP program could improve knowledge, attitudes, and skills about species. The LO evaluation of the CSP program showed that the indicator of participants' interest in science and environment increased higher than the others. The program can be used as an alternative in increasing species literacy in the public.

Introduction

Indonesia is one of the 17 mega biodiversity countries with at least two-third of all non-fish vertebrates and three-quarters of all higher plant species (Sutarno & Setyawan, 2015). The latest data on Indonesia's biodiversity shows a trend

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of new species discovery. Currently, 91,251 species of sporing plants have been identified, 19,232 species of spermatophytes, 3,982 species of vertebrates, 197,974 invertebrates, 5,137 arthropods, and 151,847 insects (Darajati et al., 2016).

Biodiversity can be an asset in Indonesia's current and future development. By changing the pattern of development from a resource-based to a science-and-technology-based country, Indonesia can be a developed country (Jompa et al., 2019). Biodiversity values are generally classified into intrinsic and existential values (Laverty et al., 2003). Biodiversity can provide biological resources, ecosystem services, biological products, and social and cultural benefits (Darajati et al., 2016; Treweek, 2001).

As a mega biodiversity country, Indonesia is faced with the challenge of a high threat of biodiversity loss (Chakrabarti, 2021; Cleary & DeVantier, 2011). The greatest threat to general biodiversity loss is human activities (Ceballos et al., 2017; Dirzo et al., 2014), their threats include habitat destruction due to destruction and changes in forest function, over exploitation, natural disasters, the introduction of invasive species, and pollution also contribute (Groom et al., 2006; Hambler, 2004; Hunter & Gibbs, 2006; Medrizam et al., 2004). Habitat destruction due to the conversion of forest to oil palm land also contributes greatly to Indonesia's biodiversity loss (The Zoological Society of London, 2011). In addition to the high loss of biodiversity, Indonesia is also faced with high levels of biopiracy which causes the loss of local genetic resources (Darajati et al., 2016).

To reduce the rate of biodiversity loss and the loss of local genetic resources due to biopiracy, the government must apply strict legal rules. Besides, public awareness should be built through various means such as policies, education, and research by the government as agreed in the Convention on Biological Diversity (CBD) congress at Rio de Janeiro Brazil in 1992 (United Nations, 1992). Building public awareness through education can be an effective way to build biodiversity literacy in the community. Formal and informal biodiversity education can be an effective alternative because it can build public awareness as UNESCO's vision of Education for Sustainable Development (ESD) by raising environmental issues, climate change, biodiversity, and sustainability as important issues in education today (United Nations Educational Scientific and Cultural Organization [UNESCO], 2017).

Biodiversity education as an important part of the issues raised in the CBD must be implemented from primary to tertiary education. Various countries such as Finland have included biodiversity education in their curriculum structures with the main material on the introduction to species and biodiversity (Wolff & Skarstein, 2020). In the structure of the Indonesian education curriculum, biodiversity teaching materials have become an important part of biology learning. The content of textbooks on the concept of biodiversity used in Indonesia has almost the same quality as that used in America and South Korea (Sakir & Kim, 2021).

The importance of knowledge about species and biodiversity in the structure of the education curriculum in Finland is also of particular concern in other European countries. Various studies conducted in Europe found low species knowledge in children (Bebbington, 2005; Kaasinen, 2019; Palmberg et al., 2015). The research on adults also found almost the same findings (Dallimer et al., 2012). The study of Tosh et al. (2016) found that many people in the UK do not know the names of the plant and animal species they encounter every day, which indicates a decline in the quality of taxonomy teaching which causes a decline in species literacy in the community. Low species literacy causes weak protection of endangered species and biodiversity (Hooykaas et al., 2019).

In the context of Indonesia as a mega biodiversity country, knowledge of biodiversity must be an important concept in biology learning at the elementary school to university level. The low species literacy in Indonesia is at least reflected in a study by Diana et al. (2019) which concludes that students have difficulty in identifying various rare plant species as well as a customs report stating that the high smuggling of endangered animals is influenced by the field officers that cannot identify various protected species of animals and plants well (Bea, 2015). The research conducted by Sugandi and Susilawati (2018) found results that were almost the same as Diana et al. (2019)

research that students' skills in classifying species were still relatively low.

Building awareness of biodiversity can be started from community knowledge about species (Kaasinen, 2019; Skarstein & Skarstein, 2020). Biology teachers have an important role in introducing species to students and the wider community; thus, the education of pre-service biology teachers must be equipped with adequate species literacy skills so that they can contribute to the protection of species and biodiversity through the delivery of quality information to students and the community.

The species literacy in pre-service biology teachers can be improved through the Citizen Science Project (CSP) activity. Citizen science (CS) is public involvement in scientific research to develop new knowledge and solve problems of everyday life (Bonney et al., 2009; Zizka, 2017). CS has now transformed as a means to produce research data fast and reach a wide area through online citizen science activities (Gray et al., 2017; Theobald et al., 2015; Van Haeften et al., 2021). CSP is widely used in improving community literacy related to biodiversity such as the biodiversity of butterflies (Lewandowski & Oberhauser, 2017), birds (McCaffrey, 2005), invasive species (Crall et al., 2013), and insects (Falk et al., 2019).

This study aims to determine the implementation of CSP on species literacy in pre-service biology teachers with the following research question formulation.

RQ1: What is the achievement of species literacy among pre-service biology teachers who are involved in the CSP program?

RQ2: What are the perceptions of pre-service biology teachers towards the implementation of the CSP program?

RQ3: How are the learning outcomes of the CSP program evaluated for pre-service biology teachers?

Method

Participant

This quasi-experiment involves 82 pre-service biology teachers from two universities in West Java, namely IAIN Syekh Nurjati Cirebon and Universitas Majalengka. The CSP approach was used with two different projects, namely monitoring of insect pollinators of mango (*Mangifera indica*) inflorescence (Project I)

and monitoring of butterfly biodiversity in citrus (*Citrus amblycarpa*) plantations (Project II). Project I was carried out by 68 pre-service biology teachers at IAIN Syekh Nurjati Cirebon while project II was carried out at Universitas Majalengka by 14 participants.

Procedure

In the implementation of this study, pre-service biology teachers were involved in observations and monitoring to determine the insect species that play a role in mango (*Mangifera indica*) inflorescences in the participant's environment (Project I) and observe butterfly biodiversity in citrus (*Citrus amblycarpa*) plantations (Project II). Research participants had to document, identify species, and upload the data obtained on the Google Form provided and to the iNaturalist application (*https://www.inaturalist.org*).

Instrument

The instruments used in this study consisted of a test and questionnaire. The test consisted of species literacy in the form of an ability test to identify the insect pollinator species of mango (*Mangifera indica*) inflorescence and butterfly species of citrus (*Citrus amblycarpa*) plantation. In the pre-test, the participants identified 14 insect pollinator species images taken on the *https://www.discoverlife.org/* (Project I) and 12 butterfly species images from https://ftp.funet.fi/ (Project II). In the post-test, 14 insect pollinator species of mango (*Mangifera indica*) inflorescence and 12 butterfly species were identified from the photos of research results of the participants (Table 1), and they were described according to the field findings. During the observation, participants collaborated to identify research data using a guideline and database available on www.inaturalist.org and the iButterflies application.

Table 1. Species literacy test item

Taxa:

Description:

Can you identify the butterfly species?

Figure by Nurul Anwar (Research participant)

The second instrument is a questionnaire on the perceptions of the learning outcomes of the CSP program and the LO evaluation of the CSP program. The LO evaluation of CSP activities aims to determine the impact of the activities on the participants. The evaluation framework used refers to six indicators, namely interest in science and the environment, self-efficacy, motivation, knowledge of science and the environment, inquiry skills, and behavior towards the environment (Phillips et al., 2014).

Data analysis

The qualitative data obtained were analyzed using descriptive-analytic techniques. The quantitative data were analyzed using a statistical Wilcoxon test with SPSS version 25. They were then interpreted according to the findings.

Results and Discussion

Species literacy in pre-service biology teachers (RQ1)

The results of the species literacy test on research participants showed an increase in the acquisition of test scores. The implementation of CSP activities carried out by participants in the form of observing insect and butterfly species has an impact on increasing species literacy. The complete test results can be seen in Table 2.

Table 2 shows the acquisition of pre-test and posttest scores as well as the N-gain of species literacy skills. The achievement of species literacy for pre-service biology teachers in Project I and Project II was in the medium category, meaning that the CSP activities carried out contributed quite well to increasing the species literacy in participants. The following are the results of statistical testing using SPSS 25 on CSP activities carried out by the participants.

Table 3 shows statistical testing using the Wilcoxon test on the achievement of species literacy in pre-service biology teachers before and after participating in CSP activities. Statistically, there is a significant increase in species literacy achievement between before and after

participating in the CSP program. It can be concluded that CSP activities have a significant impact on increasing species literacy in pre-service biology teachers as participants in CSP activities.

Pre-service biology teacher perceptions on the implementation of citizen science project activities (RQ2)

The perception of prospective biology teacher students towards implementing the CSP program shows a positive attitude towards these activities. According to participants' perceptions, the CSP program can improve knowledge, attitudes, and skills in species identification. The following are the results of recapitulation of student perceptions of the LO of CSP activities.

Based on Figure 1, the perception of pre-service biology teachers towards the implementation of the CSP program is good, indicated by the "Yes" answer greater than "No" in all projects participated. The participants perceive that CSP activities can improve their knowledge, attitudes, and skills regarding species, especially insect pollinators and butterflies (*Ordo Lepidoptera*). The complete recapitulation of responses from the CSP program participants is summarized in Figure 2.

Figure 2 shows a recapitulation of the overall perception of pre-service biology teachers towards the implementation of the CSP program. Most participants in Project I and Project II stated that CSP activities could improve their knowledge, attitudes, and skills to identify insect pollinator species of mango (*Mangifera indica*) and butterflies (*Ordo Lepidoptera*) in citrus (*Citrus amblycarpa*) plantations.

Evaluating the learning outcome of citizen science project (RQ3)

The LO evaluation of CSP activities aims to determine the impact of the activities carried out on the interests, self-efficacy, motivation, knowledge, inquiry skills, and behavior of participants. The results of the LO evaluation show that interest in science and the environment is the indicator that has the highest increase among other indicators. The evaluation of LO of CSP recapitulation is presented in Figure 3.

Table 2. Result of literacy species test

Project Name	Pre-test	Post-test	N-gain	Category
Project I	34.93	57.60	0.34	Medium
Project II	32.14	56.63	0.36	Medium

Table 3. Result of Wilcoxon test

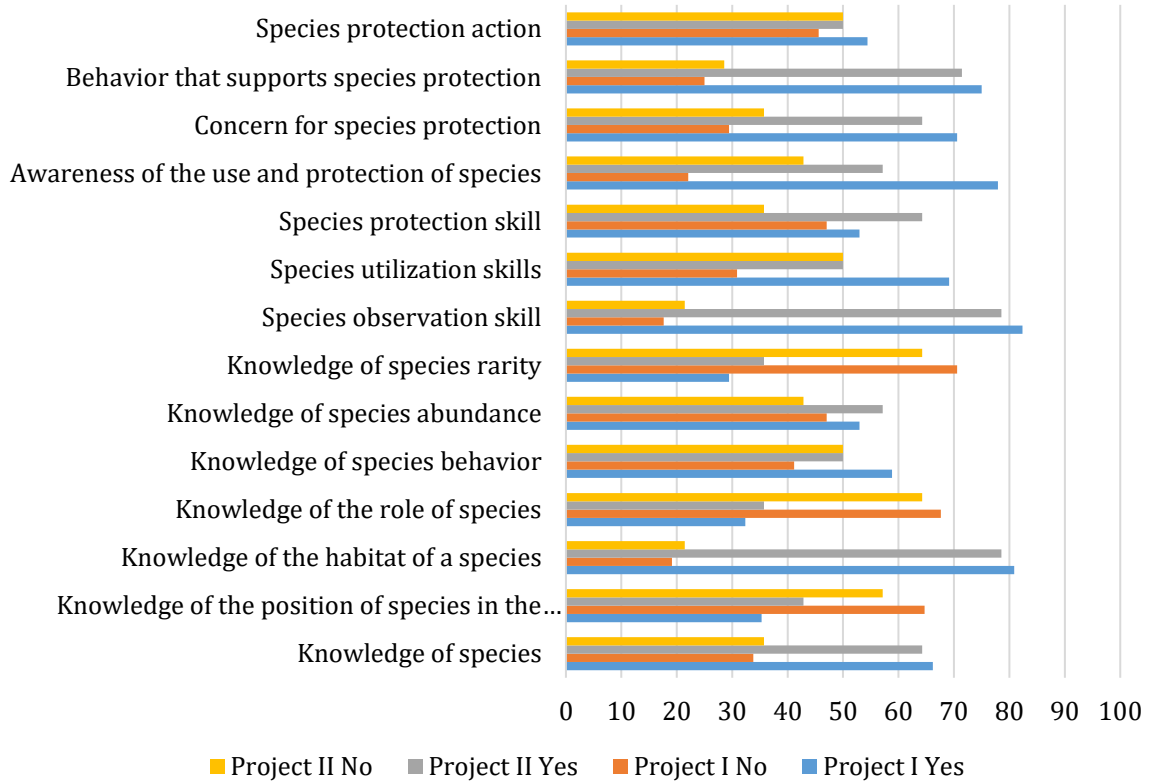|	Project I	Project II
Z	-6.976	-3.314
Asymp. Sig. (2-tailed)	0.000	0.000
Conclusion	Significant	Significant

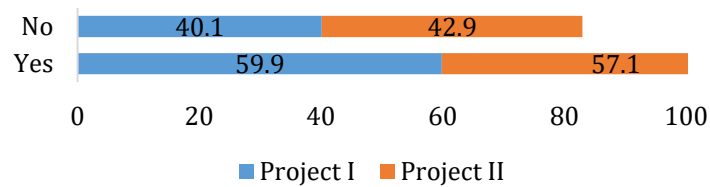Figure 1. Participants' perceptions of the CSP program

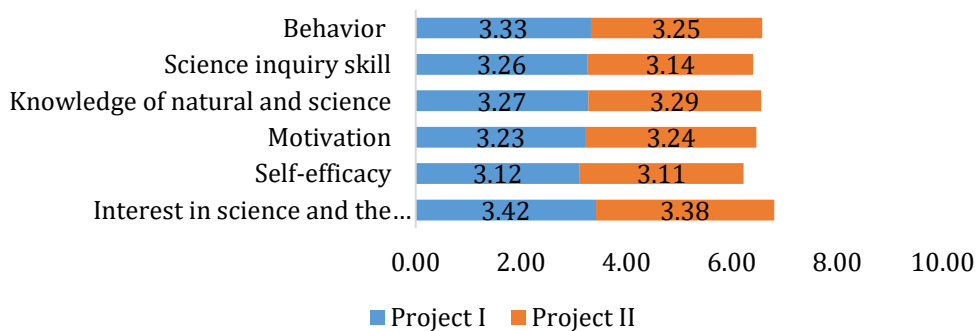Figure 2. Recapitulation of participants' perceptions of the CSP program

Figure 3. Result of the evaluation CSP program

Figure 3 shows that the evaluation results of the CSP program show that the indicator of interest in the science and environment obtains the highest achievement while self-efficacy obtains the lowest achievement. The overall achievement of the LO evaluation of the participants ranged from 3.11 to 3.42 (good), meaning that the CSP program made a positive contribution to the learning outcomes of the participants.

Species literacy is broad and in-depth knowledge of species which includes knowledge of species position, habitat, behavior, abundance, and rarity of species (Hooykaas et al., 2019). Species literacy is a skill about species that requires a fundamental understanding of the concepts of species and speciation (Aldhebiani, 2018). It can be concluded that species literacy is knowledge, competence, and skills related to species such as observation skills and application of species-related knowledge.

Species literacy can be an important part of biodiversity education, ecological literacy, environmental literacy, and biodiversity literacy (Roth, 1992; Trombulak et al., 2004). Species literacy has an important role as the basis for understanding biodiversity and related issues such as the relationship between species and their environment. Species literacy is a sub-category of biodiversity literacy (World Wildlife, 1996). The importance of species literacy in the community, one of which, is contributing to building public awareness of the importance of sustainability and protection of species (Hooykaas et al., 2019; Skarstein & Skarstein, 2020).

Species literacy in each person can be influenced by their interest in certain species (such as birds and bees) (Falk et al., 2019; Randler & Heil, 2021). Age and level of education will affect the literacy level of one's species (Hooykaas et al., 2019). The age of the participants in the present study ranged from 19 to 21 years. With increasing age, education, and experience, one's literacy species is expected to increase. By joining certain communities such as Bee Watch, Bird Watch can increase literacy in participants (Falk et al., 2019; Randler & Heil, 2021).

In the study, most participants had a positive perception of the implementation of the CSP program (Figure 3). They considered this program helped increase knowledge, attitudes, and skills about species. Pre-service biology teachers should have good knowledge of species so that they can explain about nature, answer the curiosity of students, explain the relationship between species and their role in the environment, and are the basis for understanding biodiversity and ecology (Randler, 2008; Wolff & Skarstein, 2020). Mastery of biological content (Pedagogical content knowledge/PCK) is important to be mastered by pre-service biology teachers (Großschedl et al., 2014). Knowledge of species is the foundation of systematic learning (animals and plants) at the university (Gerl et al., 2021; Kaasinen, 2019).

The CSP program has been proven to improve the learning outcomes for the participants. CSP can improve all aspects of learning outcomes for participants, especially motivation towards the environment (Peter et al., 2021). Insect monitoring activities through the CSP program have been proven to increase PCK and concern for biodiversity and conservation (Lewandowski & Oberhauser, 2017; Scheuch et al., 2018). Overall, CSP activities make a positive contribution to various aspects such as community (Jordan et al., 2012), social dimension, and knowledge (Shirk et al., 2012). The CSP program has not been widely developed in Indonesia, both at the primary, secondary, and higher education levels, so the development of CSP in education in Indonesia is potential.

CSP programs in various countries have shown a positive impact on education. This program allows students learners to be active in learning while improving inquiry-based learning so that it has been widely used in learning and research (Mitchell et al., 2017; Oberhauser & LeBuhn, 2012). CSP can increase experience in conducting research (Bonney et al., 2009), growing knowledge, and environmental research (Ballard & Belsky, 2010). Esmaeilian et al. (2018) revealed that CSP can be integrated into engineering learning. Mitchell et al. (2017) stated that CSP has benefits in increasing students' knowledge, awareness, self-confidence, and research skills. The CS program at the university level can be achieved by involving students in data collection and analysis.

The results of this study found that CSP activities can increase active participation in learning. Participants

actively observe, identify species of insects and butterflies. These activities can improve research skills and interest in science and the environment. Identification skills and use of photographic techniques to document actively moving species such as insects need to be continuously trained so that participants can identify species accurately with good quality photos. The phenetic method can be used as an alternative in taxonomy learning to improve species literacy in learners further (Hidayat, 2017).

Conclusion

The species literacy of pre-service biology teachers in the initial test was still relatively low. The research participants had difficulty identifying species and determining the position and the role of species in the ecosystem. The CSP program for monitoring insects and butterflies (*Ordo Lepidoptera*) could increase species literacy in participants with moderate categories. Most participants stated that the implementation of CSP could improve their knowledge, attitudes, and skills to identify insect pollinator species of mango (*Mangifera indica*) inflorescence and butterfly (*Ordo Lepidoptera*) biodiversity in citrus (*Citrus amblycarpa*) plantations. The results of the LO evaluation of the CSP program showed that the indicator of interest in science and the environment had the highest achievement, and self-efficacy was the indicator with the lowest achievement. The CSP program can be an alternative solution in training the achievement of species literacy for pre-service biology teachers.

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