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Implementation of the Merdeka Curriculum Using Citizen Science Project Weather-it to Improve Critical Thinking Skills of Junior High School Students

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Abstract: The Merdeka curriculum requires teachers and educational units to provide project activities in student learning. The project activities aim to improve students' skills, one of which is critical thinking. This study aims to see the feasibility of the citizen science project, Weather-it, as part of project activities in the Merdeka curriculum to improve students' critical thinking skills. This study uses the Pre-experimental method with the One-Group Pretest-Posttest Design. A total of 42 grade 7 students at a junior high school in Bandung took part in the citizen science project, Weather-it. The validated pre-test and post-test questions were made and used to analyze the improvement of students' critical thinking skills. This increase can be seen from changes in the average pre-test and post-test scores and by calculating the N-Gain score. The results showed an increase in the average value of students' critical thinking, from 48.75 (pre-test) to 70.41 (post-test). The N-Gain score states the effectiveness of the citizen science project, Weather-it, where 57.1% of students are in the medium category, 28.6% in the high category and 14.3% in the low category. Likewise, the results reflect how the citizen science project, Weather-it, can be implemented as part of implementing the Merdeka curriculum.

Keywords: Citizen science project; Critical thinking skills; Merdeka curriculum

Introduction

Education is an important thing to build the progress of a country. Indonesia as a developing country always strives to improve and increase the quality of education. This is done with the aim of forming a generation that is intelligent and able to compete at the global level. One of the efforts made by the Indonesian government at this time is to change the education system from the old paradigm to a new paradigm. The hacking of the new paradigm education system has spawned a new curriculum as a refinement of the 2013 curriculum (K-13) which is named the Merdeka curriculum. The Merdeka curriculum has one of the main characteristics, namely project-based learning. Every subject teacher, including Natural Sciences (IPA) subject teachers, is encouraged to provide project-based learning. Learning science with projects aims to develop soft skills and student character (Kemendikbud, 2022). One of the student's soft skills that can be developed through project-based learning is critical thinking skills or critical thinking skills (Anggraini et al., 2022).

The urgency of developing students' critical thinking skills has been felt in the last few decades. This is none other than because students as young people must be prepared to face the job market and the demands of society in the 21st century which are marked by relatively fast changes and progress, not only in the technological aspect but in the social and economic aspects where education is very important for the growth of a nation (Syafitri et al., 2021). For example, the US Department of Education states that graduates do not have sufficient thinking skills needed for employment. In addition, the majority of employers surveyed by companies such as the Workforce Solutions Group, Adecco, and the United States National

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Association of Colleges and Employers reported that prospective employees are unable to think critically in solving problems that occur (Uribe-Enciso et al., 2017). This fact directly affects educational institutions because their graduates are future workers, employers or leaders so that education must help students deeply instill critical thinking skills to improve their future decision-making (Crittenden et al., 2019).

Critical thinking is a person's skills in thinking logically, answering problems well, and being able to make decisions rationally (Susilawati et al., 2020). Critical thinking skills are not skills that are inherent in humans from birth. Critical thinking skills must be trained in the learning process. Aspects of critical thinking indicators according to Ennis (2011), include: 1) Providing simple explanations, 2) Building basic skills, 3) Drawing conclusions, 4) Providing further explanations, and 5) Setting strategies and tactics.

Research conducted by Hujjatusnaini et al. (2022), Early et al. (2019), and Mutakinati et al. (2018) shows that students' critical thinking skills can be improved through citizen science project-based learning. Citizen science project is a process where students can take an active role in scientific discovery. Students participate in research activities led by professional researchers to learn about phenomena that occur in nature (Phillips et al., 2018). Such learning can show students the relevance of science to their own lives while promoting the scientific profession in the field of science (Greving et al., 2022). In addition, previous research stated that citizen science has the potential to improve student learning outcomes (Phillips et al., 2018). This is due to an increase in students' knowledge about certain scientific objects (Hsu et al., 2019; Somerwill et al., 2022). In particular, several citizen science projects are designed to improve students' skills (Bruckermann et al., 2021; Santori et al., 2021).

Studies on student involvement in citizen science projects in Indonesia (AWC and EPI) have never been carried out. Researchers previously designed their own citizen science projects which they used for formal learning such as butterfly diversity citizen science (Aripin et al., 2021), flower plant diversity citizen science (Rachmawati et al., 2022) and biodiversity citizen science (Damayanti et al., 2021). The design of a citizen science project depends on the learning objectives to be achieved from these activities. Makuch et al. (2018) have recognized that if a citizen science project is properly designed, students can be actively involved in citizen science project activities, where they can learn and contribute to research. In particular, if the citizen science project is integrated into the school curriculum, student involvement can add value to formal education (Harlin et al., 2018).

Several citizen science projects based on school curricula have been reported describing evaluations of student or teacher experiences with the program (Frigerio et al., 2018; Pitt et al., 2018). Student and teacher engagement outcomes are most often assessed using pre-post surveys that determine the extent of student learning (Kocman et al., 2020) and the most interesting aspects of science (Frigerio et al., 2018). For example, Pitt et al. (2018) found that after participating in a research project with the United States Forest Service, students showed greater interest in natural resource management careers. While Frigerio et al. (2018) found that students were least interested in data entry and most excited by specific hardware tasks. Researchers also noted project alignment with mandatory curriculum requirements through project inclusion in the curriculum (Pitt et al., 2018) or through informal feedback from teachers after work was completed (Saunders et al., 2018).

Citizen science projects are applied on many topics to raise awareness and can be a tool for environmental and conservation issues (Heinisch, 2021). Citizen science projects provide opportunities to generate new knowledge, enable learning, facilitate environmental knowledge, build capacity, and enable community participation (Turrini et al., 2018). Smart mobile devices and online networks are also useful for citizen scientists for data collection, storage, and dissemination (Weigelhofer et al., 2019). As in the citizen science project, Weather-it, which uses mobile devices during project activities.

Citizen science project, Weather-it, is a scientific weather investigation activity. Citizen science project, Weather-it, can provide broad opportunities for students to learn weather through direct observation (Echeverria et al., 2021; Kelemen-Finan et al., 2018; Panitsa et al., 2021; Queiruga-Dios et al., 2020). Citizen science project, also provides learning about the scientific method (Echeverria et al., 2021; Queiruga-Dios et al., 2020). Students learn how to collect data, process and draw conclusions according to scientific principles (Ballard et al., 2017; Peter et al., 2021; Weigelhofer et al., 2019).

Thus, this research is important to do because the citizen science project, Weather-it, can be a new innovation in science learning in Indonesia and support the implementation of the Merdeka curriculum. The questions in this research are: 1) How is the citizen science project, Weather-it, implemented as part of the independent curriculum learning at the junior high school level? 2) How is the application of the citizen science project, Weather-it towards improving the critical thinking skills of junior high school students? While the aims of this research are: 1) To analyze how far the Citizen science project, Weather-it, can become part of the independent curriculum at the junior high

school level; 2) Analyze how far the Citizen science project, Weather-it, can improve students' critical thinking skills.

Method

The research method used in this study was pre-experimental with a one-group pretest-posttest design. Sampling was done through purposive sampling technique. The sample in this study were 7th grade students consisting of 42 students, 11 male students and 31 female students.

The treatment variable in this study is the citizen science project, Weather-it, while the dependent variable is critical thinking skills. The citizen science project, Weather-it, will last for two weeks, from 01 August 2022 to 10 August 2022 involving BMKG (Meteorology Climatology and Geophysics Council) teachers and meteorologists. The teacher plays the role of monitoring the activities of the Weather-it project with researchers. Meanwhile, meteorologists are presented to provide students with in-depth knowledge about the weather. Students are given the opportunity to have direct discussions with meteorologists in two meetings. The first meeting was conducted offline, namely during a weather investigation, while the second meeting was held online during the presentation of the results of the investigation. Furthermore, students will collect weather data on Wednesday, 03 August 2022 from 07.30-16.30 WIB using the AccuWeather application. Students are also given the mission to observe clouds with their family members using the Globe Observer application for two consecutive days, namely on 6 and 7 August 2022. As for the citizen science project activity scheme, weather-it can be seen in Figure 1.

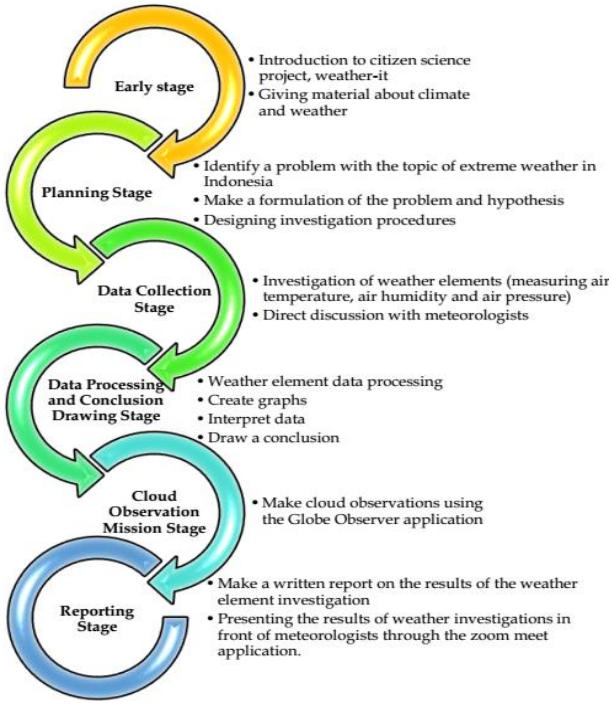

Figure 1. Citizen science project activities, weather-it

The instruments used in data collection in this study consisted of three parts, namely written tests, performance appraisal sheets and semi-structured interviews. Students' critical thinking skills were measured using a written test with a total of 11 essay questions. The indicators for achieving students' critical thinking skills as measured in this study refer to the five indicators put forward by Ennis (2011). This test is used for assessing students' Pre-test and Post-test. Details of critical thinking indicators and the number of questions can be seen in Table 1.

Table 1. Indicators for Students' Pre-Test and Post-Test Questions

Group Aspect	Indicator	Number of Questions
Elementary clarification	Focusing questions	3
	Analyze arguments	
	Ask and answer challenging questions	
Basic support	Considering credibility (criteria of a source)	2
	Observe and consider the results of observations	
Inference	Create an induction and consider an induction	2
	Make and consider value decisions	
Advance clarification	Define terms and consider them	2
	Identify assumptions	
Strategies and tactics	Decide on an action	2
	Interact with others	

The questions on the test have been validated by two experts and have been tested to determine the feasibility of the instrument. The correlation coefficient and reliability of the questions that have been made are 0.59 and 0.74, respectively. Performance assessment sheets are used to assess students' written reports. Students are given the task of making a report on the results of their weather investigation. The indicators of critical thinking that are assessed on the performance appraisal sheet are deciding an action and interacting with others.

While semi-structured interviews were conducted to see student and teacher responses to the activities of the citizen science project, Weather-it. The results of the interviews can provide important information related to project implementation. This information can be in the form of obstacles, weaknesses and strengths, as well as the benefits felt by students and teachers during project activities in implementing the Merdeka curriculum.

The data obtained from the written test will be analyzed by comparing the pre-test and post-test average scores for all critical thinking indicators and for each critical thinking indicator. Students' critical thinking skills increase if the student's post-test score is higher than the student's pre-test score (Hujjatusnaini et al., 2022). This increase can be analyzed by calculating the N-gain score. The interpretation of the N-gain score refers to the classification according to Hake (2002) which is presented in Table 2.

Tabel 2. Normalized Gain (N-Gain) Index Score

Category	N-gain
High	$g \geq 0.7$
Medium	$0.3 < g < 0.7$
Low	$g \leq 0.3$

Result and Discussion

Implementation of the Citizen Science Project, Weather-It

Citizen science project, Weather-it with the theme "climate change: global warming". This theme corresponds to the main theme of the project in the independent curriculum, namely a sustainable lifestyle. In this theme students are expected to be able to understand the impact of human activity on the continuity of life on earth. Students are also expected to learn about potential sustainability crises that occur in their surroundings and develop readiness to face and mitigate them (Kemendikbud, 2022).

The first stage: students identify weather problems that occur due to climate change. Problem identification was carried out by students by reading an article about flooding during the dry season. Students also watch two videos, the first video is about the causes and effects of climate change while the second video is about extreme weather that is happening in Indonesia. After identifying the problem, students make a problem statement and then submit a hypothesis. Finally, students create a research plan for weather investigations. This first stage takes 180 minutes (3 hours). At this first stage, students have difficulty identifying problems and formulating problems. The video presented needs to be played twice so that students can find the essence of the problem in each video.

The second stage: students carry out a weather investigation, namely measuring air temperature, air humidity and air pressure using the AccuWeather application for 8 hours. Measurements are taken every hour from 07.30 WIB to 16.30 WIB. Students are divided into 3 groups, each group investigates the weather in a different place. The first group conducted a weather investigation in a place with lots of trees, the second group in a place with few trees and group 3 in a school parking lot where there were no trees.

The weather investigation stage is the activity stage that students like the most. Based on the results of the interviews, 99% of students stated that the most enjoyable activities for them were activities in the field when conducting weather investigations.

KI: "*It's great to be able to do research in the field. Although tired from morning to evening, but fun*".
FN: "*The most exciting activity was during the investigation from morning to evening*".

The science teacher who took part in the citizen science project activities agreed with what was expressed by the students. Teachers realize that innovation in science learning is needed, one of which is learning outside the classroom.

Science teacher: "*I have to develop ideas to provide learning that is not boring for students. Because I observe my students feel bored and bored with learning that is only in class. They need learning outside the classroom*".

According to Taqwan (2019), learning that takes place outside the classroom can add aspects of joy and fun to students because students do not feel burdened with learning. They feel they are playing in nature.

Apart from carrying out weather investigations, in this second stage students also carry out direct discussions with meteorologists. They discussed differences in climate and weather, causes of climate change and weather, impacts of climate change and weather, the relationship between climate and weather parameters (air temperature, air humidity and air pressure) and how the BMKG predicts the weather. Meteorologists visit one by one the student groups where they carry out weather investigations so that discussions can be more conducive and intense.

Figure 2a shows the activity of students learning to identify the weather and types of clouds with meteorologists. Then figure 2b shows the activities of students discussing with meteorologists. Students feel proud and happy because they can meet and discuss with a scientist.

(a) ((b)

Figure 2. (a) Activities to identify weather and cloud types with scientists; (b) Direct discussion activities with scientists (BMKG meteorologists)

AZ: "*I feel happy because I can meet people from BMKG. Not everyone has the opportunity to meet scientists*".
NL: "*I feel proud because I can ask scientists directly*".

Having discussions with scientists gives confidence to students (Aristeidou et al., 2020). Students feel more confident with their mastery of science content after discussing with a scientist (Ballard et al., 2017). This sense of pride and joy has shaped students' self-efficacy (Kocman et al., 2020).

Weather investigation activities and direct discussions with scientists also provide in-depth knowledge to students. Students become more understanding about air temperature, humidity, and air pressure.

FN: "*I became more understanding about air temperature, air humidity and air pressure. Now, I know that air temperature, air humidity and air pressure can change at any time. I also learned that air temperature and humidity are opposites. When the air temperature is high, the air humidity will be low*".

According to Kelemen-Finan et al. (2018) and Phillips et al. (2018), citizen science projects can support increasing students' knowledge regarding science content through the provision of material by scientists/researchers. This increase in knowledge can be seen more after conducting investigations in citizen science projects (Aristeidou et al., 2020; Kelemen-Finan et al., 2018; Kocman et al., 2020). This is understandable because in weather investigation activities students do not just listen but practice directly on the knowledge they have acquired.

The third stage: students carry out an analysis of the weather parameter data they obtained during a weather investigation. Students input data on Ms. Excel, then creates a graph of the data. The resulting graph is used by students to draw a conclusion from the results of their investigation. Students deduce the average, maximum, and minimum values of each weather parameter they measure. At this stage, students learn to make graphs (Ballard et al., 2017) and interpret the meaning of the project data presented in these graphs (Peter et al., 2021). One student stated that he could understand how to input data on Ms. Excel but he forgot how to make graphs in Ms. Excel. This can happen because training in making graphs with Ms. Excel is only done once without repetition. Training on making graphs should be carried out more than once so that students' skills in making graphs can increase (Ballard et al., 2017).

The fourth stage: the "observing the clouds" mission using the Globe Observer application. At this stage, students are given a mission to observe clouds for two consecutive days with their family members. Observations can be made in the morning, afternoon or evening. A total of 29 students successfully carried out their mission, 10 students only observed clouds for one day, while 3 other students did not observe clouds at all. Obstacles faced by students who did not complete their mission include: internet network and cellphone conditions with errors.

Figure 3. Cloud observation activities with family members

Figure 3 shows the interaction between students and their family members when observing clouds. Students invite their mother or father or other family members, then students teach their family members about the Globe Observer application and how to identify clouds.

KF: "*I observe clouds with mom and dad. I taught them how to use the globe observer application, I also taught them what to observe. Until mom said that I was great, I already knew a lot. So I feel proud to be said to be great with mom*".

The cloud observation data that students generate will be stored in the Globe Observer application (Figure 4). Furthermore, students can send this data to NASA (National Aeronautics and Space Administration) because the Globe Observer application is a citizen science application that has collaborated with NASA.

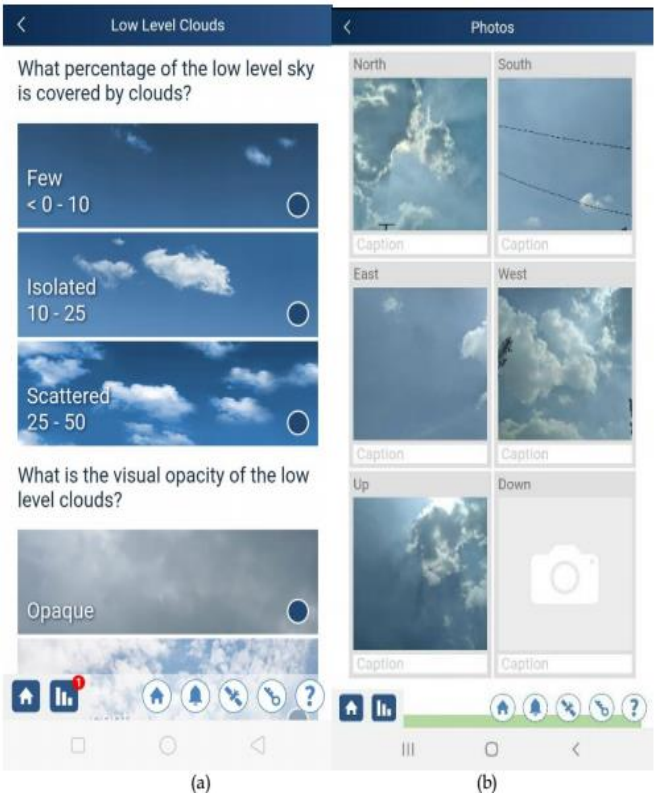

Figure 4. (a) Examples of questions found in the Globe Observer when students observe clouds; (b) Cloud observation data that will be sent to NASA

RF: "*I'm happy and proud to be able to send data to NASA, so when I'm observing the clouds I'm more careful*".

One of the special features of citizen science project activities is the delivery of data or publication of data on scientific or semi-scientific platforms (Schleicher, 2020). The observation mission given to students in the citizen science project, Weather-it, is to collect cloud data that can be sent to NASA data. Contributing to NASA data makes students feel happy and proud because the data they get can be published and side by side with the data produced by experts (Echeverria et al., 2021; Kermish-Allen et al., 2019).

Fifth stage: presentation of weather investigation results. Three groups of students made presentations for 25 minutes in front of scientists. However, the scientist was not present directly at the student's presentation. Scientists also listen to the course of student presentations through the Zoom Meeting application. However, the presentation continued to run smoothly.

RA: "*I was nervous about presenting in front of scientists, but now I know how to make a good presentation*".
KY: "*So we know how to speak in front of the class especially when there are scientists*".

At this stage students learn to communicate with others directly. Previous research has revealed that itizen science projects can improve students' communication skills through publication or presentation activities (Aristeidou et al., 2020; Ballard et al., 2017; Kocman et al., 2020; Peter et al., 2021).

Based on the results of semi-structured interviews with science teachers, the citizen science project, Weather-it, can be part of the independent curriculum as a learning project and can even be used as a project to strengthen the Pancasila profile. Implementation is easy and does not take too long.

Science teacher: "*This project is great. Could be an annual project*".

However, there are several things that need to be considered, including: 1) schools have limitations in inviting an expert/scientist to be involved in activities; 2) the citizen science project, weather-it, only focuses on science subjects, while the project to strengthen the Pancasila profile requires collaborating on several subjects.

In this study, the activities designed only focused on learning natural sciences. However, if we examine more deeply the citizen science project, Weather-It, it is rich in knowledge such as technology and informatics (TIK) where students learn using Ms. Excel to process data. Citizen science project, Weather-It, can also teach Social Sciences (IPS) to students, namely during cloud observation activities with family members. In that case, they learn to convey something to their family members. They are also cardinal directions, latitudes and longitudes because when observing clouds using the Globe Observer, they must determine the cardinal directions, latitudes and longitudes. Apart from TIK and IPS, students also study mathematics and English. They gain mathematical knowledge from interpreting data in the form of tables and graphs. As for English, they learn through cloud observation because the language used in the globe observer application is English. Thus, there are actually many other subjects in the citizen science project, Weather-It.

Students' Critical Thinking Skills

Overall critical thinking skills can be seen based on the average pre-test and post-test scores. The maximum score for critical thinking skills is 100 out of 11 essay questions. Based on the data processing that has been done, the overall average score of students' critical thinking skills after carrying out the citizen science project activities, Weather-it, has increased (Figure 5).

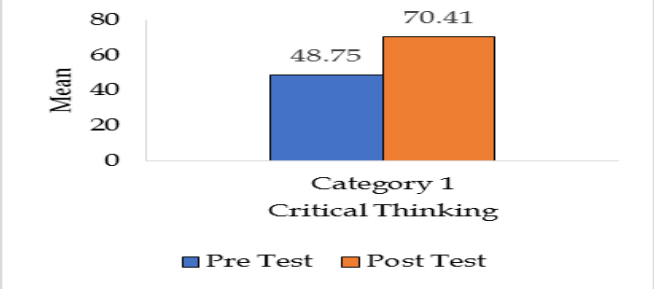

Figure 5. The average value of the pre-test and post-test of all indicators

Previous research has shown that project learning provides significant results in improving critical thinking skills (Hujjatusnaini et al., 2022; Mutakinati et al., 2018). Critical thinking skills are high-level thinking skills that are able to activate students' abilities to identify problems, analyze, evaluate, and conclude (Rahman et al., 2021). In this study used inquiry syntax. The syntax reflects a scientific-based inquiry process as the basis for learning activities. Through the application of this model it provides a meaningful learning experience to students (Wahyudiati, 2022). Students carry out inquiries in citizen science activities, Weather-it, which include experiences in identifying problems, formulating goals and hypotheses, designing and conducting independent experiments, and making conclusions. The N-gain results for students' critical thinking skills can be seen in Figure 6.

Figure 6 shows that the highest increase in students' critical thinking is in the medium category. Meanwhile, the number of students in the high category was more than the low category. Students have the highest skills on the indicator "ask and answer challenging questions" before treatment while after treatment, the highest indicator is "interact with others" (Figure 7). This is in line with the results of the assessment of student worksheets where students have a "good" skill level on the interact with others indicator and the "adequate" category on the on an action indicator. The lowest students' critical thinking skills before treatment were in the "identify assumptions" indicator while after treatment, namely "focus on questions" (Figure 7).

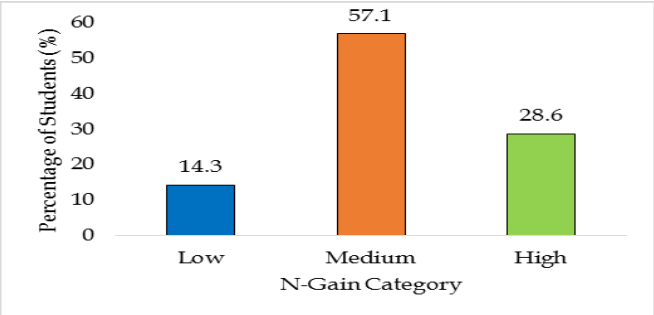

Figure 6. Analysis of critical thinking improvement based on N-Gain score

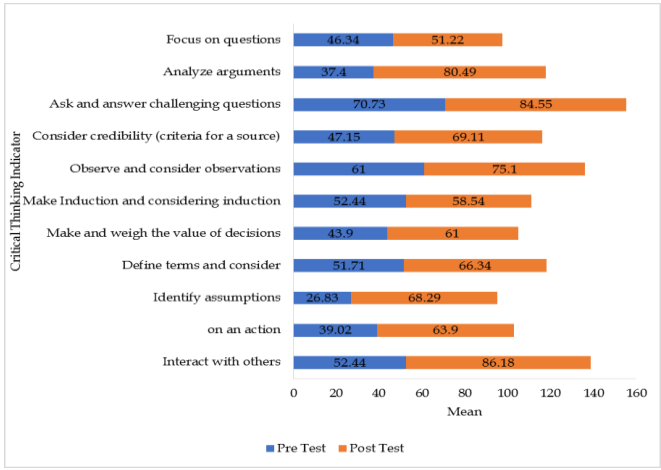

Figure 7. The average value of pre-test and post-test for each indicator of critical thinking

Citizen science, Weather-it, provides student-centered learning. Students are required to be responsible, help each other, exchange opinions, ideas and ideas and manage time at the investigation stage (Fitriani et al., 2019). Through project activities, students are invited to think critically about environmental problems around them (Yusuf, 2022).

Conclusion

The citizen science project, Weather-it, can be implemented as part of the independent curriculum learning and can even be used as a project to strengthen the Pancasila profile, provided that there is a need for collaboration with other subjects. The benefits that students feel by participating in the citizen science project, Weather-it, include feeling proud and happy during the field investigation process, gaining in-depth knowledge about the weather, and gaining knowledge about technology. In addition to the citizen science project, Weather-it can also improve students' critical thinking skills where students' post-test scores are higher than pre-test scores. Most students, namely 51.7%, are in the medium category for the N-gain score, which means that the increase in students' critical thinking skills is at a moderate level.

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References

Anggraini, N. S., Hamidah, D., & Rahayu, D. S. (2022). Analisis Kemampuan Berpikir Tingkat Tinggi Siswa pada Materi Relasi dan Fungsi Kelas VIII Di SMPN 1 Tanjunganom. *Jurnal Pendidikan Matematika (Jupitek)*, *4*(2), 79–86. https://doi.org/10.30598/jupitekvol4iss2pp79-86

Aripin, I., Hidayat, T., & Rustaman, N. (2021). Monitoring Biodiversitas Kupu-Kupu Di Perkebunan Jeruk Limau (Citrus amblycarpa) Berbasis Citizen Science. *Gunung Djati Conference Series*, *6*, 2021. https://conference.uinsgd.ac.id/index.php/

Aristeidou, M., Scanlon, E., & Sharples, M. (2020). Learning outcomes in online citizen science communities designed for inquiry. *International Journal of Science Education, Part B: Communication and Public Engagement*, *10*(4), 277–294. https://doi.org/10.1080/21548455.2020.1836689

Ballard, H. L., Dixon, C. G. H., & Harris, E. M. (2017). Youth-focused citizen science: Examining the role of environmental science learning and agency for conservation. *Biological Conservation*, *208*, 65–75. https://doi.org/10.1016/j.biocon.2016.05.024

Bruckermann, T., Greving, H., Schumann, A., Stillfried, M., Börner, K., Kimmig, S. E., Hagen, R., Brandt, M., & Harms, U. (2021). To know about science is to love it? Unraveling cause-effect relationships between knowledge and attitudes toward science in citizen science on urban wildlife ecology. *Journal of Research in Science Teaching*, *58*(8), 1179–1202. https://doi.org/10.1002/tea.21697

Crittenden, W. F., Biel, I. K., & Lovely, W. A. (2019). Embracing Digitalization: Student Learning and New Technologies. *Journal of Marketing Education*, *41*(1), 5–14. https://doi.org/10.1177/0273475318820895

Damayanti, D. F., Solihat, R., & Hidayat, T. (2021). Upaya Meningkatkan Research Skill Siswa Melalui Citizen Science Project Pada Pembelajaran Biologi Sma. *BIOEDUKASI (Jurnal Pendidikan Biologi)*, *12*(2), 133. https://doi.org/10.24127/bioedukasi.v12i2.4438

Echeverria, A., Ariz, I., Moreno, J., Peralta, J., & Gonzalez, E. M. (2021). Learning plant biodiversity in nature: The use of the citizen–science platform inaturalist as a collaborative tool in secondary education. *Sustainability (Switzerland)*, *13*(2), 1–12. https://doi.org/10.3390/su13020735

Ennis, R. (2011). Critical Thinking: Reflection and Perspective Part II. *Inquiry: Critical Thinking Across the Disciplines*, *26*(2), 5–19. https://doi.org/10.5840/inquiryctnews201126215

Fitriani, R., Surahman, E., & Azzahrah, I. (2019). Implementasi Pembelajaran Berbasis Proyek Untuk Meningkatkan Kemampuan Berpikir Kritis Siswa the Implementation of Project Based Learning To Improve Critical Thingking Skill Student. *Quagga: Jurnal Pendidikan Dan Biologi*, *11*(1), 6–12. https://journal.uniku.ac.id/index.php/quagga

Frigerio, D., Pipek, P., Kimmig, S., Winter, S., Melzheimer, J., Diblíková, L., Wachter, B., & Richter, A. (2018). Citizen science and wildlife biology: Synergies and challenges. *Ethology*, *124*(6), 365–377. https://doi.org/10.1111/eth.12746

Greving, H., Bruckermann, T., Schumann, A., Straka, T. M., Lewanzik, D., Voigt-Heucke, S. L., Marggraf, L., Lorenz, J., Brandt, M., Voigt, C. C., Harms, U., & Kimmerle, J. (2022). Improving attitudes and knowledge in a citizen science project about urban bat ecology. *Ecology and Society*, *27*(2). https://doi.org/10.5751/ES-13272-270224

Hake, R. R. (2002). Relationship of individual student normalized learning gains in mechanics with gender, high-school physics, and pretest scores on Mathematics and Spatial Visualization. *Physics Education Research Conference*, *8*(August 2002), 1–14. https://rb.gy/8ycc

Harlin, J., Kloetzer, L., Patton, D., & Leonhard, C. (2018). Turning students into scientists. *Chemical and Engineering News*, *33*(48), 5162–5163. https://doi.org/10.1021/cen-v033n048.p5162

Heinisch, B. (2021). The Role of Translation in Citizen Science to Foster Social Innovation. *Frontiers in Sociology*, *6*(33). https://doi.org/10.3389/fsoc.2021.629720

Hsu, C. H., Chang, Y. M., & Liu, C. C. (2019). Can short-term citizen science training increase knowledge, improve attitudes, and change behavior to protect land crabs? *Sustainability (Switzerland)*, *11*(14). https://doi.org/10.3390/su11143918

Hujjatusnaini, N., Corebima, A. D., Prawiro, S. R., & Gofur, A. (2022). the Effect of Blended Project-Based Learning Integrated With 21St-Century Skills on Pre-Service Biology Teachers' Higher-Order Thinking Skills. *Jurnal Pendidikan IPA Indonesia*, *11*(1), 104–118. https://doi.org/10.15294/jpii.v11i1.27148

Kelemen-Finan, J., Scheuch, M., & Winter, S. (2018). Contributions from citizen science to science education: an examination of a biodiversity citizen science project with schools in Central Europe. *International Journal of Science Education*, *40*(17), 2078–2098. https://doi.org/10.1080/09500693.2018.1520405

Kemendikbud. (2022). *Panduan Pengembangan Projek Penguatan Profil Pelajar Pancasila*. Kementerian Pendidikan, Kebudayaan, Riset, dan Teknologi.

Kermish-Allen, R., Peterman, K., & Bevc, C. (2019). The

utility of citizen science projects in K-5 schools: measures of community engagement and student impacts. *Cultural Studies of Science Education*, *14*(3), 627–641. https://doi.org/10.1007/s11422-017-9830-4

Kocman, D., Števanec, T., Novak, R., & Kranjec, N. (2020). Citizen science as part of the primary school curriculum: A case study of a technical day on the topic of noise and health. *Sustainability (Switzerland)*, *12*(23), 1–15. https://doi.org/10.3390/su122310213

Makuch, K., & Aczel, M. (2018). *Children and Citizen Science: In Citizen Science: Innovation in Open Science, Society and Policy*. London, UK: Press.

Mutakinati, L., Anwari, I., & Yoshisuke, K. (2018). Analysis of students' critical thinking skill of middle school through stem education project-based learning. *Jurnal Pendidikan IPA Indonesia*, *7*(1), 54–65. https://doi.org/10.15294/jpii.v7i1.10495

Panitsa, M., Iliopoulou, N., & Petrakis, E. (2021). Citizen science, plant species, and communities' diversity and conservation on a mediterranean biosphere reserve. *Sustainability (Switzerland)*, *13*(17). https://doi.org/10.3390/su13179925

Peter, M., Diekötter, T., Kremer, K., & Höffler, T. (2021). Citizen science project characteristics: Connection to participants' gains in knowledge and skills. *PLoS ONE*, *16*(7 July 2021), 1–30. https://doi.org/10.1371/journal.pone.0253692

Phillips, T., Porticella, N., Constas, M., & Bonney, R. (2018). A Framework for Articulating and Measuring Individual Learning Outcomes from Participation in Citizen Science. *Citizen Science: Theory and Practice*, *3*(2), 3. https://doi.org/10.5334/cstp.126

Pitt, A. N., & Schultz, C. A. (2018). Youth-based citizen science monitoring: Case studies from three national forests. *Journal of Forestry*, *116*(2), 109–116. https://doi.org/10.1093/jofore/fvx008

Queiruga-Dios, M. Á., López-Iñesta, E., Diez-Ojeda, M., Sáiz-Manzanares, M. C., & Dorrío, J. B. V. (2020). Citizen science for scientific literacy and the attainment of sustainable development goals in formal education. *Sustainability (Switzerland)*, *12*(10), 4283. https://doi.org/10.3390/su12104283

Rachmawati, N., Hidayat, T., & Supriatno, B. (2022). Analysis of Citizen Science-Based Flowering Plant Diversity Worksheet Development to Improve Students' Critical Thinking Ability. *Bioedukasi*, *20*(2), 38. https://doi.org/10.19184/bioedu.v20i2.34613

Rahman, M. M., Doyan, A., & Sutrio, S. (2021). Efektifitas Perangkat Pembelajaran Pendekatan Multi Representasi Berbantuan Video Untuk Meningkatkan Kemampuan Berpikir Kritis Peserta Didik. *Jurnal Penelitian Pendidikan IPA*, *7*(SpecialIssue), 56–60. https://doi.org/10.29303/jppipa.v7ispecialissue.1063

Santori, C., Keith, R. J., Whittington, C. M., Thompson, M. B., Van Dyke, J. U., & Spencer, R. J. (2021). Changes in participant behaviour and attitudes are associated with knowledge and skills gained by using a turtle conservation citizen science app. *People and Nature*, *3*(1), 66–76. https://doi.org/10.1002/pan3.10184

Saunders, M. E., Roger, E., Geary, W. L., Meredith, F., Welbourne, D. J., Bako, A., Canavan, E., Herro, F., Herron, C., Hung, O., Kunstler, M., Lin, J., Ludlow, N., Paton, M., Salt, S., Simpson, T., Wang, A., Zimmerman, N., Drews, K. B., … Moles, A. T. (2018). Citizen science in schools: Engaging students in research on urban habitat for pollinators. *Austral Ecology*, *43*(6), 635–642. https://doi.org/10.1111/aec.12608

Schleicher, A. (2020). The impact of COVID-19 on education: Insights from education at a glance 2020. *OECD Journal: Economic Studies*, 1–31.

Somerwill, L., & Wehn, U. (2022). How to measure the impact of citizen science on environmental attitudes, behaviour and knowledge? A review of state-of-the-art approaches. *Environmental Sciences Europe*, *34*(1), 1–13. https://doi.org/10.1186/s12302-022-00596-1

Susilawati, E., Agustinasari, A., Samsudin, A., & Siahaan, P. (2020). Analisis Tingkat Keterampilan Berpikir Kritis Siswa SMA. *Jurnal Pendidikan Fisika Dan Teknologi*, *6*(1), 11–16. https://doi.org/10.29303/jpft.v6i1.1453

Syafitri, E., Armanto, D., & Rahmadani, E. (2021). Aksiologi Kemampuan Berpikir Kritis. *Journal of Science and Social Research*, *4307*(3), 320–325. http://jurnal.goretanpena.com/index.php/JSSR

Taqwan, B. (2019). Pengaruh Pembelajaran Luar Kelas (Outdoor Learning) Terhadap Kemampuan Pemecahan Masalah Siswa Kelas VII SMP Negeri 05 Seluma. *Jurnal Pendidikan Matematika Raflesia*, *4*(1), 10–18. https://doi.org/10.33449/jpmr.v4i1.7524

Turrini, T., Dörler, D., Richter, A., Heigl, F., & Bonn, A. (2018). The threefold potential of environmental citizen science - Generating knowledge, creating learning opportunities and enabling civic participation. *Biological Conservation*, *225*, 176–186. https://doi.org/10.1016/j.biocon.2018.03.024

Uribe-Enciso, O. L., Uribe-Enciso, D. S., & Vargas-Daza, M. D. P. (2017). Critical thinking and its importance in education. *Rastros Rostros*, *19*(34), 204–208. https://doi.org/10.16925/ra.v19i34.2144

Wahyudiati, D. (2022). Critical Thinking Skills and Scientific Attitudes of Pre-Service Chemistry

Teachers Through the Implementation of Problem-Based Learning Model. *Jurnal Penelitian Pendidikan IPA*, *8*(1), 216–221. https://doi.org/10.29303/jppipa.v8i1.1278

Weigelhofer, G., Pölz, E. M., & Hein, T. (2019). Citizen science: How high school students can provide scientifically sound data in biogeochemical experiments. *Freshwater Science*, *38*(2), 236–243. https://doi.org/10.1086/698765

Yusuf, Y. (2022). Improving Students' Critical Thinking Skills Against Environmental Problems: Practicum Mini Project "Understanding Public Perceptions of Environmental Problems." *Jurnal Penelitian Pendidikan IPA*, *8*(1), 209–215. https://doi.org/10.29303/jppipa.v8i1.1224