Shih, JL. et al. (Eds.) (2023). Proceedings of the 31st International Conference on Computers in Education. Asia-Pacific Society for Computers in Education

A Proposal for Mobile-assisted Citizen Inquiry Learning Approach in Learning of Plastic Pollution

Chawadol SRIBOONPIMSUAY[a*], Niwat SRISAWASDI[a,b,c*]
[a]*Faculty of Education, Khon Kaen University, Thailand*
[b]*Smart Learning Innovation Research Center, Khon Kaen University, Thailand*
[c]*Digital Education and Learning Engineering Association of Thailand, Thailand*
*niwsri@kku.ac.th

Abstract: Engaging young people in citizen inquiry could facilitate the process of constructing learning outcomes through investigation and reflection on their experiences. This study aimed to investigate the effects of using the citizen inquiry approach on students' learning outcomes regarding environmental awareness, scientific explanation, and scientific communication. An intensive science camp regarding the citizen inquiry approach to plastic pollution has been developed and implemented for elementary school students. The results showed considerable improvement in their learning outcomes after interacting with the intervention. However, there is a challenge and opportunity to redesign the implemented approach with the support of mobile technology to improve their learning outcomes. This paper proposes how we could transform the citizen inquiry approach with digital devices to promote elementary school students' environmental awareness, scientific explanation, and scientific communication.

Keywords: Citizen science, inquiry-based learning, environmental awareness, scientific communication, scientific explanation

1. Introduction

Currently, there is a growing global trend in citizen science initiatives to reduce the amount of plastic pollution in the environment. Citizen science is an approach that involves the public in scientific research related to scientists' interests (Silvertown, 2009). This approach allows people to participate in scientific projects and collect and analyze data, regardless of their educational background (Aristeidou et al., 2013). By engaging the public in citizen science, individuals can learn about science in a real-life context and bridge the gap between scientific communities and the general public (Bonney et al., 2014; Herodotou et al., 2014). For example, Ballard et al. (2017) studied and analyzed two youth-focused programs, called Environmental Science Agency. It aimed to link conservation learning and action. They found the program enhanced various aspects of environmental science agency. Despite the growth of youth participation in citizen science, studies on achieving rigorous environmental education and conservation science are scarce.

Addressing plastic pollution through citizen science is effective for youth education. Despite the integration of environmental issues into school curricula increasing (Rickinson & Lundholm, 2008), current methods still have limitations in fostering youth environmental awareness (Dalu et al., 2020; Robertson & Krugly-Smolska, 1997). To promote the application of citizen science in the school education context, Herodotou et al. (2018) proposed citizen inquiry, a transformative approach combining inquiry-based learning and citizen science. It aims to involve citizens in all scientific inquiry stages including the conception of a project, the definition of research objectives, the selection of methods for data collection and analysis, and the implementation of research. Moreover, Aristeidou et al. (2020) used online citizen inquiry to scaffold students in scientific processes during citizen science activities, reporting meaningful involvement and practice of inquiry skills.

In the process of citizen inquiry, mobile or smartphone are beneficial leaning tools. It can provide learners with access to a wide range of resources, facilitating data collection and analysis, and promoting collaboration and engagement (Sharples et al., 2015; Suárez et al., 2018). Thus, there is a need to develop better version of citizen inquiry approach to promote their environmental awareness and motivation among individuals (Henderson & Green, 2020; Williams et al., 2019). Furthermore, scientific competencies, such as scientific explanation and communication, are also crucial outcome for learning science by citizen inquiry.

In conclusion, promoting young people to learn science through citizen inquiry addressing environmental issue, such as plastic pollution, requires not only scientific inquiry skills, but also environmental awareness, scientific explanation, and effective scientific communication. This study aims to investigate an effect of traditional citizen inquiry learning integrated open inquiry approach on students' environmental awareness, scientific explanation, and scientific communication, and introduce a proposal for a mobile-assisted citizen inquiry learning approach in learning of plastic pollution for elementary school students.

2. Review of Literature

2.1 Citizen Science and Citizen Inquiry

Citizen science, a growing field involving the public in scientific projects, benefits both the public and scientific community through quality data collection and increased scientific literacy (Bonney et al., 2009). However, its traditional model has been criticized for limiting research questions and participant diversity (Haklay, 2013; Jordan et al., 2011). The citizen inquiry approach addresses these limitations by encouraging active knowledge construction (Dewey, 1916; Hmelo-Silver et al., 2007), empowering citizens to make informed decisions (Sharples et al., 2013) and merging elements of citizen science and inquiry-based learning (Aristeidou et al., 2013).

In 2014, citizen inquiry was defined as a research collaboration involving scientists and the public (Herodotou et al., 2014). it combines principles of inquiry-based learning and citizen science for relevant, authentic investigations (Aristeidou et al., 2017). It also bridges the gap between citizen science and inquiry-based learning in informal education (Aristeidou et al., 2017).

2.2 Citizen Inquiry of Plastic Pollution

Citizen inquiry into plastic pollution has grown since the 1990s, with initiatives like the International Coastal Cleanup (ICC) launched in 1986, involving volunteers in beach cleanups and data collection on plastic debris, informing policy decisions (*International Coastal Cleanup*, 2017) Recent projects include the Plastic Citizen project, where young people collected data on plastic pollution (Burden et al., 2021) and the "Plastic Pirates" program, allowing students to collect and share data about riverbank trash (Gudrun, 2022).

These initiatives show citizen inquiry's effectiveness in addressing environmental concerns and its role in scientific processes. Thus, citizen inquiry has been instrumental in tackling plastic pollution, leading to policy and behavioral changes.

2.3 Inquiry-Based Learning and Guided-inquiry Process

Scholars have indicated inquiry-based learning strategies can support students in constructing and developing content knowledge and enhancing comprehension of the scientific investigation (Srisawasdi & Panjaburee, 2019). Inquiry-based learning involves students actively participating in scientific investigations, exploring concepts, and fostering inquiry skills (National Research Council, 2000). On the other hand, guided inquiry learning offers students guidance throughout the process. It includes a series of steps that steer students through the inquiry process which would help them gain necessary knowledge and skills (Bell et al., 2009). It can be seen as a part of inquiry-based learning with more teacher involvement.

Guided inquiry engages students in investigations and simulations related to environmental issues, helping them understand the impact of human activities on the environment and explore the causes, effects, and solutions to these problems (Sholahuddin et al., 2020). It also provides opportunities for students to ask questions, design investigations, analyze data, and construct scientific explanations based on evidence (Stone, 2014). Furthermore, it enhances scientific communication skills through activities such as presenting findings, writing lab reports, and participating in scientific discussions, enabling students to communicate scientific information clearly and effectively to different audiences (Sarwi et al., 2018).

2.4 Mobile-Assisted Learning in Citizen Inquiry Approach

Mobile-assisted learning is using mobile devices to support learning. While, citizen inquiry is a way of engaging citizens in scientific research. Those can be combined for effective learning experiences. Mobile devices provide easy access to information, real-time data recording, and facilitate collaboration among citizen scientists. They also offer interactive learning through educational apps and gamified activities (Herodotou et al., 2019; Kukulska-Hulme, 2011).

Research indicates that mobile-assisted learning enhances engagement, motivation, and understanding in citizen inquiry. Kukulska-Hulme (2011) found that mobile devices improved engagement, motivation, and understanding of scientific concepts related to air pollution. Similarly, Herodotou et al. (2019) found that mobile-assisted learning facilitated data collection, analysis, and collaboration among participants.

3. Methodology

3.1 Participants

The study was conducted as an intensive science camp with 29 students aged 10-12 years old from Demonstration School of Khon Kaen University, international division Thailand. The camp took place both within and outside the school premises, all within the university area.

3.2 The Intensive Science Camp

A -day science camp was designed in the plastic pollution theme to help students recognize the effect of plastic on the surrounding environment through the plastic problem and experiment. All activities were created using citizen inquiry and guided inquiry. All activities in the camp were conducted mainly in English with some Thai in the section where students seemed struggle to understand.

The camp was divided into three stages: Ignite, Explore, and Evaluate, based on the work of Srisawasdi & Kroothkeaw, (2014). How the experimental procedure of the intensive science camp was conducted was shown in Figure 1.

In the ignite stage, it consists of two sub-processes and there was a total of 25 minutes. The first sub-process is an inquiry question. In the process, students were presented with an question entailing their investigative inquiry in a real context as citizen (15 minutes). They will use the inquiry question as a main compass to explore the rest of the learning missions in the camp. In the second sub-process, a series of scientific background and information related to the question has been provided to students for engaging their existing ideas and information about plastic pollution and microplastic (10 minutes).

In the explore stage, this stage also contains two sub-process and there was a total of 195 minutes. The first sub-process is investigative procedures, and they were described all the learning missions for the camp (20 minutes).

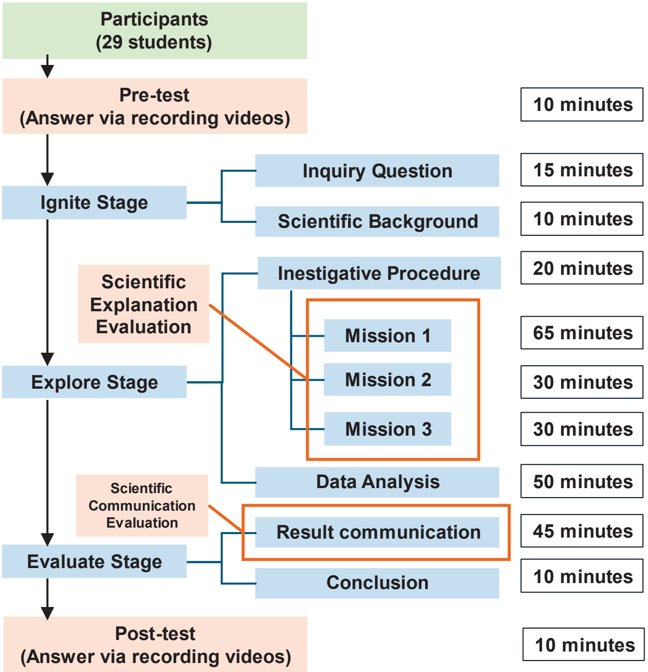


Figure 1. Experimental Procedure of The Intensive Science Camp

For the investigative procedures, there were three citizen inquiry-related practices consisting of plastic waste investigation (65 minutes), microplastic lab investigation (30 minutes), and plastic circular economy investigation (30 minutes). Figure 2 illustrates the three learning missions in the camp intervention.

Figure 2. Illustrative examples of learning mission 1 (left), learning mission 2 (middle), and learning mission 3 (right)

In Figure 2, the three inquiry learning missions could be described as follows.

Mission 1 - What can you tell me about these plastics? This mission was conducted using a field-based collaborative inquiry approach using quadrat sampling methods. Students will count the amount of plastic, living things and vegetation in the designated 4-square meters plotted area. It was adapted from Ghaffari et al., (2019).

Mission 2 - Can you trust what you see? Students will try to find microplastics in the given water sample. In this mission was adapted from “Microplastics in the Classroom” mission of Blue Ocean Society, (2022). Each group explored the microplastics in the given water sample with portable microscope kit which was attached to their mobile devices.

Mission 3 - The 4 Rs: Students will –explore the feasible ways of reducing plastic pollution by using 4Rs from the 9R Framework of Kirchherr et al., (2017), which are – Reduce, Reuse, Recycle and Repurpose. Students worked in groups to study stations set up by researchers and were guided by a facilitator.

The second sub-process of the explore stage is data analysis. students gather and analyze data from all missions Then, combining quantitative and qualitative data to form a conclusive explanation.

In the evaluation stage, it consists of two sub-processes with 55 minutes. The first sub-process, result communication (45 minutes), is where students were asked to explain and communicate their understanding. Then, they exchanged ideas on plastic pollution solutions with peers and teachers.

In the last sub-process of the evaluation stage (10 minutes). This is when researchers and students try to conclude the whole key concept of the camp and answer question together. This would also depict the whole system of plastic pollution from plastic production to soil settlement and water contamination which, eventually, come back to harm humans.

3.3 Data Collection

Students' environmental awareness was assessed before and after the camp through video-recorded responses to questions about plastic pollution. It then were scored using framework of Lederman et al. (2014). Scientific explanation was assessed through three worksheets designed to assess their scientific explanation according to the framework of Mcneill (2008). Scientific communication was evaluated through a final video-recorded response. Then scored based on work of Lederman et al. (2014). The transcriptions were also analyzed to depict the level of circularity in the chosen Rs of students and to interpret the effect of the treated intervention on their understanding. Scores were given based on whether they stated, mentioned, or offered information that was previously presented in the intervention.

3.4 Analysis of data

3.4.1 Environmental Awareness

Students individually answered three questions related to Missions 1-3 via video. Transcriptions were evaluated by two experts for environmental awareness at three levels - naïve, mixed, and informed. Any disagreements were resolved through discussion until consensus was reached. Then, scores before and after each mission were compared and depicted in a line graph to compare changes in students' environmental awareness due to the intervention.

3.4.2 Scientific Explanation

The worksheets from mission 1-3 were given to students. After the camp is finished, each worksheet was examined for the level of each component – claim, evidence, and reasoning – using the criteria of McNeil (2008). Then it went through the process of grouping. If the students had a similar score in each component, they fell into same group e.g., if student has level 0 cross claim, evidence, and reasoning, they will fall into group 000 – where each number describes the level of each element respectively. After that, the frequency of the students in each group was counted to determine the abundance of the students in each group.

3.4.3 Scientific Communication

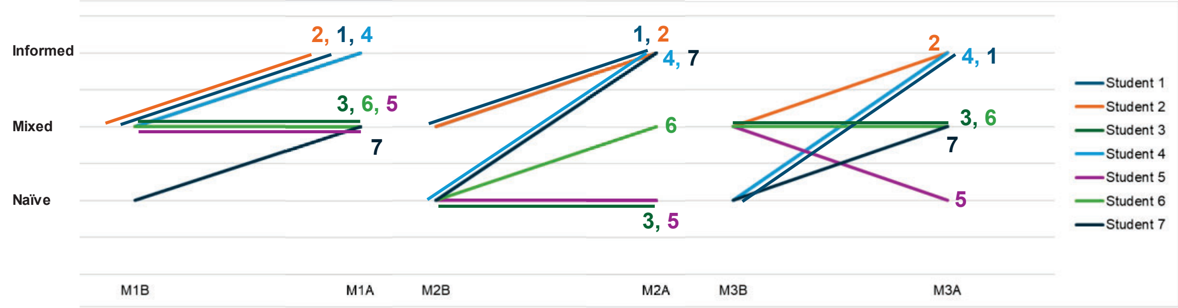
All students were presented with a final question. They answered by recording video. Then the video transcriptions were scored within three levels – naïve, mixed, and informed. The frequency was counted and calculated as percentage. Also, the level of circularity was analyzed based on the work of Kirchherr et al., (2017). The scores -2, -1, +1, and +2 were assigned to recycle, repurpose, reuse, and reduce respectively. If the multiple Rs were chosen, it would be assigned to the highest score. This was assigned to the X axis.

The comprehension in the camp intervention was evaluated and given score -1 and 1 were given to each criterion where 1 was given when the answer was true and vice versa. The sum calculation was made to determine the total number of scores. This will be the Y-axis. The data from the individual was plotted to create bubble graph.

4. Result

4.1 Environmental Awareness

To depict the comparison of change of the score, the line graph was created in Figure 3. It is important to note the data collection occurred at the end of the camp day. Some students may have been absent due to early pick-up, which should be considered when interpreting the results.



B = Level of environmental awareness from mission 1 before camp
A = Level of environmental awareness from mission 1 after camp
M2B = Level of environmental awareness from mission 2 before camp
M2A = Level of environmental awareness from mission 2 after camp
M3B = Level of environmental awareness from mission 3 before camp
M3A = Level of environmental awareness from mission 3 after camp

Figure 3. Result of Environmental Awareness for Individual Student. Comparing Between Before and After the Camp of 3 Missions

In mission 1, most students showed noticeable improvement from ‘Naïve’ to ‘Mixed’ or ‘Mixed’ to ‘Informed’ levels after the camp (M1A), compared to before (M1B). However, some students’ scores remained unchanged. Mission 2 results were similar, with some students maintaining the same ‘Naïve’ level in both pre- and post-mission assessments (M2B and M2A). Mission 3 (M3B and M3A) showed similar trends, but interestingly, some students regressed from ‘Mixed’ to ‘Naïve’. The rest of the details was depicted in figure 3.

4.2 Scientific Explanation

Student scores were categorized into groups based on the three components of scientific explanation - claim, evidence, and reasoning. This led to further grouping into 7 categories as shown in Table 1.

Table 1 *Group Classification of Students' Level of Explanation*

Group	Description	Score
I	Score from all each component of claim, evidence, and reasoning were found to be correlated	000, 111, 222
II	Students could form claims and conduct experiments for evidence, but struggled to create the link between claim and evidence	121
III	Students could create somewhat level of claims and conducted the experiment to extract the evidence on somewhat or strong level but unable to create the link between claim and evidence.	110, 120
IV	Students could make only claim.	100
V	Students could only conduct the experiment to bring out the evidence but unable to create both claim and reasoning.	010
VI	Students trended to use their prior knowledge to create the evidence then link it with claim to create reasoning	101
VII	Students trended to make a guess when making the reasoning and ignored the stated claim.	021

Figure 4 presents the number of students in each group from Missions 1, 2, and 3. Group I had 3, 1, and 6 students for each mission respectively, but most students were in

Group III. This suggests that the intervention fostered some scientific reasoning elements, but students may have struggled to link claim and evidence to form valid scientific reasoning.

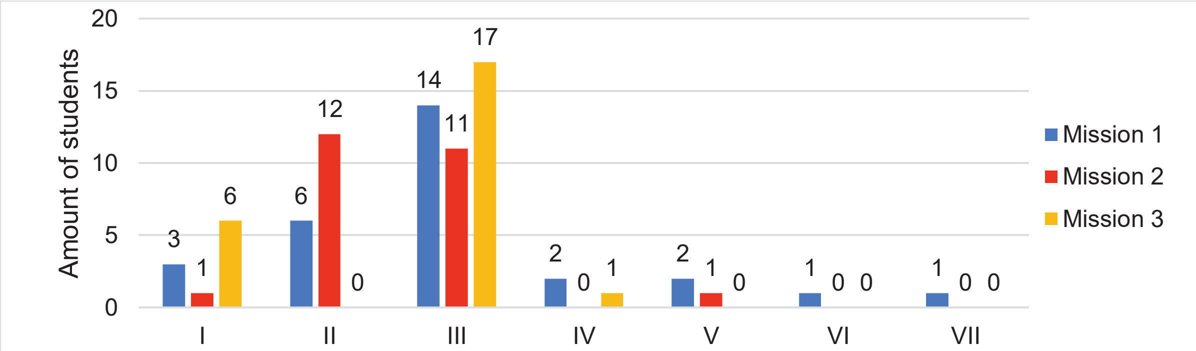


Figure 4. Number of Students in Each Group from Each Mission

The second largest - Group III- suggests that students could make claims and draw evidence from Missions 1 and 2 but struggled with reasoning. Also, group VI is notable as students seemed to use prior knowledge for reasoning, despite being unable to extract evidence from the experiment. While in group VII, students appeared to attempt reasoning despite a lack of claim.

4.3 Scientific Communication

Figure 5 shows the number of students at each level. The majority, 50% or 13 students, are at the 'naïve' level, while only 11.54% or 3 students reached the 'informed' level.

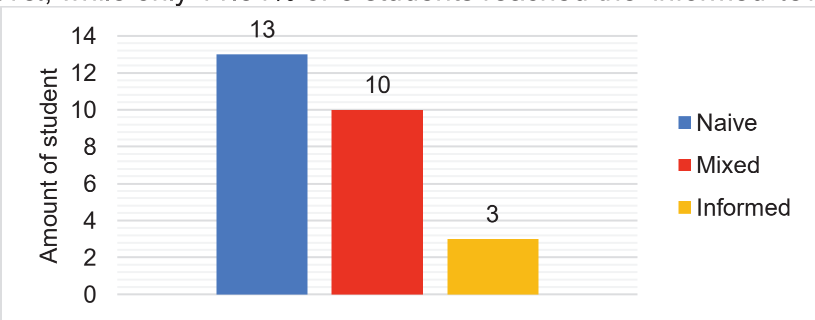


Figure 5. Number of Students from Each Level of Awareness

The correlation between the selected circularity level and their comprehension in the intervention is depicted in Figure 6. Most students fall into quadrant 2 of the graph, indicating they chose low-level circularity to tackle plastic pollution, but their statements were based on intervention information. The second largest group is in quadrant 1, indicating that they chose higher-level circularity, and their statements were based on the intervention. Few students stated information not from the intervention.

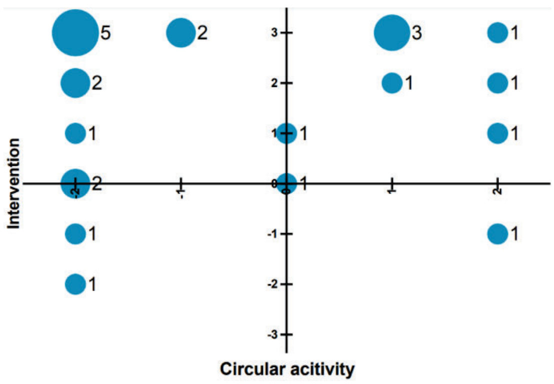


Figure 6. Result of Students' Circularity Level and Understanding

5. Discussion

The study conducted a camp with three missions to assess students' environmental awareness, scientific explanation skills, and communication abilities. The results provide valuable insights into the effectiveness of the intervention and areas for potential improvement. The camp appears to have had a positive impact on students' environmental awareness. However, some students showed no change or even regression, possibly due to a lack of exposure to environmental concepts (Hungerford & Volk, 2013). In terms of scientific explanation, most students understood parts of it but struggled to connect claims and evidence to create reasoning. This suggests that there is room for improvement in helping students form valid scientific reasoning. This could be due to insufficient topic knowledge or difficulty transferring skills to new contexts (Choowong & Worapun, 2021; Seifert et al., 2022). A lack of interest or motivation in science could also hinder the development of evidence gathering and reasoning skills (Anderhag et al., 2016).

In scientific communication, few students achieved the highest level, indicating a need for more targeted practice. Also, varying levels of prior scientific knowledge or communication abilities among students could be a contributing factor (Weigold, 2001). Most students chose low-level circularity but based their statements on intervention information, suggesting they grasped some camp concepts. However, few students stated information not from the intervention, indicating a potential gap in their understanding. Future interventions should consider strategies for differentiated instruction to foster each skill of students.

6. A Proposal for Activity Incorporated Within Technology Learning.

Although there was progress in increasing environmental awareness, explaining science, and communicating science of students, there's still space to do better in these areas. To do that, this section puts forth an idea to improve this intervention by making better use of technology. By bringing in more advanced tools during these camps, we could make the outcomes even better. To do that, the incorporation of technology and mobile learning in creative ways during the intervention should be made. For instance, instead of just reading from paper, interactive videos could be used to teach and provide information to students. Also, rather than writing on paper, students could use mobile apps to complete their assignments, which would give them quick feedback.

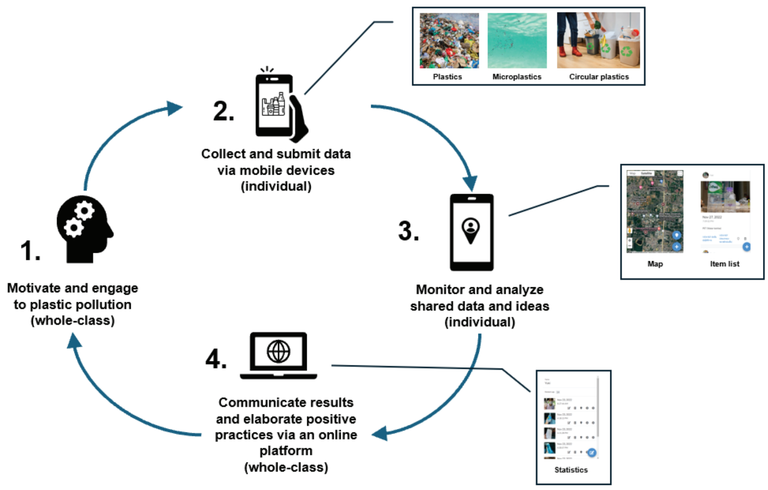


Figure 7 A Schematic Diagram of Proposed Mobile-Assisted Citizen Inquiry Approach on Plastic Pollution Phenomenon

Moreover, when doing an interview with students, it could be done online as a group instead of recording each person separately. The propose is that by using these technology tools, it can make learning more exciting and effective for students attending these camps, making them more interested in the environment and better at communicating scientific ideas. In the end, hopefully, this could potentially lead to creating young children to be more resilient and become greater global citizens. Figure 7 displays a conceptual idea of mobile-assisted citizen inquiry approach for the learning of plastic pollution.

7. Conclusion

The study found that an intervention improved students' environmental awareness and scientific reasoning, but some students responded less, and challenges remained in linking claims with evidence. Despite using guided inquiry and citizen inquiry, scientific communication skills varied among students. The intervention's success in fostering environmental awareness and scientific reasoning was noticeable, but enhancing scientific communication skills needs more comprehensive strategies.

While there were improvements, there's still room to do better. The study suggests using advanced technology tools to make learning more engaging and effective. For example, using interactive videos for teaching, mobile apps for assignments, and online group interviews. These tools could make learning more exciting, increase interest in the environment, and improve communication of scientific ideas. This could lead to the development of resilient young global citizens. A concept of a mobile-assisted citizen inquiry learning approach for learning about plastic pollution is also presented.

References

Anderhag, P., Wickman, P.-O., Bergqvist, K., Jakobson, B., Hamza, K. M., & Säljö, R. (2016). Why Do Secondary School Students Lose Their Interest in Science? Or Does it Never Emerge? A Possible and Overlooked Explanation. *Science Education*, *100*(5), 791–813.

Aristeidou, M., Scanlon, E., & Sharples, M. (2013). *A design-based study of Citizen Inquiry for geology*. 7.

Aristeidou, M., Scanlon, E., & Sharples, M. (2017). Design processes of a citizen inquiry community. In C. Herodotou, M. Sharples, & E. Scanlon (Eds.), *Citizen Inquiry* (1st ed., pp. 210–229). Routledge.

Aristeidou, M., Scanlon, E., & Sharples, M. (2020). Learning outcomes in online citizen science communities designed for inquiry. *International Journal of Science Education, Part B*, *10*(4), 277–294.

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.

Blue Ocean Society. (2022, February 22). *Microplastics in the Classroom*.

Bonney, R., Cooper, C. B., Dickinson, J., Kelling, S., Phillips, T., Rosenberg, K. V., & Shirk, J. (2009). Citizen Science: A Developing Tool for Expanding Science Knowledge and Scientific Literacy. *BioScience*, *59*(11), 977–984.

Bonney, R., Shirk, J. L., Phillips, T. B., Wiggins, A., Ballard, H. L., Miller-Rushing, A. J., & Parrish, J. K. (2014). Next Steps for Citizen Science. *Science*, *343*(6178), 1436–1437.

Burden, K., Wurzel, R., & Dean, C. (2021). *Plastic Citizen*. https://www.hull.ac.uk/work-with-us/research/case-studies/plastic-citizen.aspx

Choowong, K., & Worapun, W. (2021). The Development of Scientific Reasoning Ability on Concept of Light and Image of Grade 9 Students by Using Inquiry-Based Learning 5E with Prediction Observation and Explanation Strategy. *Journal of Education and Learning*, *10*(5), Article 5.

Dalu, M. T. B., Cuthbert, R. N., Muhali, H., Chari, L. D., Manyani, A., Masunungure, C., & Dalu, T. (2020). Is Awareness on Plastic Pollution Being Raised in Schools? Understanding Perceptions of Primary and Secondary School Educators. *Sustainability*, *12*(17).

Dewey, J. (1916). *Democracy and Education: An Introduction to the Philosophy of Education*. Macmillan.

Ghaffari, S., Bakhtiari, A. R., Ghasempouri, S. M., & Nasrolahi, A. (2019). The influence of human activity and morphological characteristics of beaches on plastic debris distribution along the Caspian Sea as a closed water body. *Environmental Science and Pollution Research*, *26*(25), 25712–25724.

Gudrun, O. (2022). *About the campaign | Plastic Pirates*. https://www.plastic-pirates.eu/en/about

Haklay, M. (2013). Citizen Science and Volunteered Geographic Information: Overview and Typology of Participation. In D. Sui, S. Elwood, & M. Goodchild (Eds.), *Crowdsourcing Geographic*

Knowledge: Volunteered Geographic Information (VGI) in Theory and Practice (pp. 105–122). Springer Netherlands.
Henderson, L., & Green, C. (2020). Making sense of microplastics? Public understandings of plastic pollution. *Marine Pollution Bulletin*, *152*, 110908.
Herodotou, C., Aristeidou, M., Sharples, M., & Scanlon, E. (2018). Designing citizen science tools for learning: Lessons learnt from the iterative development of nQuire. *Research and Practice in Technology Enhanced Learning*, *13*(1), 4.
Herodotou, C., Sharples, M., Gaved, M., Kukulska-Hulme, A., Rienties, B., Scanlon, E., & Whitelock, D. (2019). Innovative Pedagogies of the Future: An Evidence-Based Selection. *Frontiers in Education*, *4*.
Herodotou, C., Villasclaras-Fernandez, E., & Sharples, M. (2014). *Scaffolding citizen inquiry science learning through the nQuire toolkit.* 5.
Hmelo-Silver, C. E., Duncan, R. G., & Chinn, C. A. (2007). Scaffolding and Achievement in Problem-Based and Inquiry Learning: A Response to Kirschner, Sweller, and Clark (2006). *Educational Psychologist*, *42*(2), 99–107.
International Coastal Cleanup®. (2017, March 7). Ocean Conservancy.
Jordan, R. C., Gray, S. A., Howe, D. V., Brooks, W. R., & Ehrenfeld, J. G. (2011). Knowledge Gain and Behavioral Change in Citizen-Science Programs. *Conservation Biology*, *25*(6), 1148–1154.
Kirchherr, J., Reike, D., & Hekkert, M. P. (2017). Conceptualizing the Circular Economy: An Analysis of 114 Definitions. *SSRN Electronic Journal*, *127*.
Kukulska-Hulme, A. (2011). Smart learning with mobile devices? *NEW MEDIA*.
Lederman, J. S., Lederman, N. G., Bartos, S. A., Bartels, S. L., Meyer, A. A., & Schwartz, R. S. (2014). Meaningful assessment of learners' understandings about scientific inquiry—The views about scientific inquiry (VASI) questionnaire. *Journal of Research in Science Teaching*, *51*(1), 65–83.
Mcneill, K. (2008). Inquiry and Scientific Explanations: Helping Students Use Evidence and Reasoning. *Science as Inquiry in the Secondary Setting*.
Rickinson, M., & Lundholm, C. (2008). Exploring students' challenges in environmental learning. *Cambridge Journal of Education*, *38*, 341–353.
Robertson, C. L., & Krugly-Smolska, E. (1997). Gaps between Advocated Practices and Teaching Realities in Environmental Education. *Environmental Education Research*, *3*(3), 311–326.
Sarwi, S., Fauziah, N., & Astuti, B. (2018). The analysis of scientific communications and students' character development through guided inquiry learning. *Journal of Physics: Conference Series*, *983*, 012031.
Seifert, C. M., Harrington, M., Michal, A. L., & Shah, P. (2022). Causal theory error in college students' understanding of science studies. *Cognitive Research: Principles and Implications*, *7*(1), 4.
Sharples, M., Aristeidou, M., Villasclaras-Fern´andez, E., Herodotou, C., & Scanlon, E. (2015, October 17). *A Smartphone Toolkit for Citizen Inquiry Learning*. https://doi.org/10.1007/978-3-319-25684-9_27
Sharples, M., Mcandrew, P., Weller, M., Ferguson, R., FitzGerald, E., Hirst, T., & Gaved, M. (2013). *Innovating Pedagogy 2013: Exploring new forms of teaching, learning and assessment, to guide educators and policy makers*.
Sholahuddin, A., Sholihah, A., Mahdian, & Susilowati, E. (2020). Can the guided inquiry with environment learning resources increase conceptual understanding and scientific literacy? *Journal of Physics: Conference Series*, *1422*(1), 012038. https://doi.org/10.1088/1742-6596/1422/1/012038
Silvertown, J. (2009). A new dawn for citizen science. *Trends in Ecology & Evolution*, *24*(9), 467–471.
Srisawasdi, N., & Kroothkeaw, S. (2014). Supporting students' conceptual development of light refraction by simulation-based open inquiry with dual-situated learning model. *Journal of Computers in Education*, *1*(1), 49–79.
Srisawasdi, N., Panjaburee, P. (2019). Implementation of game-transformed inquiry-based learning to promote the understanding of and motivation to learn chemistry. *Journal of Science Education and Technology, 28*, 152–164. https://doi.org/10.1007/s10956-018-9754-0
Stone, E. M. (2014). Guiding Students to Develop an Understanding of Scientific Inquiry: A Science Skills Approach to Instruction and Assessment. *CBE Life Sciences Education*, *13*(1), 90–101.
Suárez, Á., Specht, M., Prinsen, F., Kalz, M., & Ternier, S. (2018). A review of the types of mobile activities in mobile inquiry-based learning. *Computers & Education*, *118*, 38–55.
Weigold, M. (2001). Communicating Science: A Review of the Literature. *Science Communication - SCI COMMUN*, *23*, 164–193.
Williams, M., Gower, R., Green, J., Whitebread, E., Lenkiewicz, Z., & Schröder, P. (2019). *No Time to Waste: Tackling the Plastic Pollution Crisis Before it's Too Late*.

W09

The First International workshop on Ethics of AIED: Challenges and Opportunities for Achieving Learner Centricity