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Promoting Core Competencies of High School Biology through Citizen Inquiry Technology: A Case of Polluting Microplastics

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Abstract: In this paper, we are designing learning activities based on 21st-century learning to help teachers or pre-service teachers to promote essential skills such as biology competencies. Learning activities need to be integrated with appropriate learning strategies with global awareness and environmental issues as core themes like the 21st-learning framework mentioned and combined with the particular technology to support biology competencies. This paper aims to provide the alternatives of learning activities using citizen inquiry and technology to develop biology skills in each activity. In addition, to describe pre-service teacher's understanding of microplastics knowledge and awareness of environmental problems. Based on the results, pre-service teacher's understanding of microplastics and awareness about the environmental issue is pretty good, with average percentages of 81.73% and 75 %, respectively. As described further in the paper, learning activities to promote biology skills can be achieved using citizen inquiry and technology. The finding could be implied in developing technological and pedagogical pre-service teacher's skills in biology education.

Keywords: Learning Activities, biology skills, citizen inquiry, technology, microplastics

1. Introduction

The development of technology and information has influenced many factors, including the education field. Therefore, the standard of competency of learning science has been adapted with the 21st-learning skills. In the framework of 21st-century learning, students must master the knowledge, skills, expertise, and literacies to succeed in work and life. Students must accomplish several essential skills, such as critical thinking, problem-solving, communication, and collaboration (OECD, 2009).

Biology competencies or biology skills is one of the competencies that must be achieved after learning biology. Clemmons et al. (2020) stated six biology competencies: a process of science; quantitative reasoning; modeling and simulation; interdisciplinary nature of science; communication and collaboration, and the relationship between nature and science. To accommodate those skills, a teacher needs the capability to conduct exciting learning activities. Also, they need to integrate the socio-scientific issues to make learning meaningful. Meaningful learning happens when integration of concept into the cognitive structure (Novak, 2002). As mentioned by OECD (2009), schools must promote understanding knowledge in the scope of 21st-century interdisciplinary themes such as global awareness and environmental literacy into core subjects.

One of the topics that can be used is environmental issues such as microplastics. The abundant number of plastics has become a global concern. Microplastic could be problematic because it could be found in the water and digested (Forrest et al., 2019). Also, it is causing potential harm to any living organism in the water (Underwood et al., 2017). As a part of global issues, learning about microplastics has become superior knowledge for students. Even though microplastic impacts the environment, the public perception and understanding of microplastic are pretty limited (Anderson et al., 2016). In addition, the current curriculum of Thailand has not yet addressed this problem correctly (Ministry of Education, 2017). Therefore, it is considered to implement the microplastic topic in learning activities.

A learning strategy that can be used to transform the knowledge of microplastics is citizen inquiry. The participating scientific process through citizen inquiry is an excellent way to increase

scientific knowledge and literacy (Philips, T et al.2018). Also, by doing so, it can enhance their competencies, especially biology skills. Using citizen inquiry to accomplish the biology skills is possible. Currently, integration between biology skills and citizen inquiry has not been applied in many schools. The application is still limited to the ability of students to do the process of science.

Many technologies can be integrated into learning using citizen inquiry. For instance, Echeverria et al. (2021) use the iNaturalist platform in an outdoor activity to learn about biodiversity. Another technology, such as portable gas-sensing air pollution, monitors air pollution (McKercher et al., 2017). Sharples et al. (2017) also use a Sense-it App sensor to measure the environmental noise, air pressure, and rainfall sunlight, speed of lifts, and sunlight levels. The use of information technology in learning is required in modern learning requires 21st-century skills.

Therefore, providing teachers or pre-service teachers the learning activities in microplastics cases is one of the alternative ways to encourage teachers to overcome the lack of knowledge about biology or socio-scientific topics. In this paper, we mainly report about the pre-service teachers understanding of microplastics and the awareness toward environmental issues and possible activities using technology in citizen inquiry conditions to promote the biology skills.

2. Literature Review

2.1 Teaching and Learning Process in Biology

Biology is a branch of science that provides explanations about natural phenomena such as living things and the process of life. The biology topics are diverse, some of them can be explained by observing nature directly, but others cannot be explained without technology/media. Besides, in learning biology, students are demanded to have biology skills. Clemmons et al. (2020) state that biology skills refer to a set of competencies developed from the Vision and Change core competency framework, consisting of 6 competencies.

- Ability to apply the process of science: have a process of science, i.e., formulating a question, interpreting data.
- Ability to use quantitative reasoning: interpret logic, math including performing a basic calculation.
- Ability to use modeling and simulation: use the model to express or communicate ideas with others.
- Ability to tap into the interdisciplinary nature of science: understand that concept of science is interdisciplinary- it includes other fields of science.
- Ability to communicate and collaborate with other disciplines: can work and share with others regardless of their expertise.
- Ability to understand the relationship between science and society: understand that science, environment, and lives are constantly influenced by each other.

Pre-service teachers are expected to have teaching competencies to teach biology subjects. One of the leading teaching competencies is Technological Pedagogical Content Knowledge (TPACK) skills. Mishra & Koehler (2006) state that the TPACK framework integrates three significant elements: technological knowledge, pedagogical knowledge, and content knowledge. Technological content knowledge refers to the knowledge about application technology to teach specific content. Technological pedagogical knowledge is related to the knowledge about how technology can be used in teaching, and pedagogical content knowledge refers to the application of general pedagogical knowledge within specific content. In addition, the learning activity needs to be organized and designed based on appropriate learning strategies such as citizen inquiry to accomplish the biology skills.

2.2 Learning about Environmental Issues through Citizen Inquiry

Designing learning activities in biology topics can use citizen inquiry. Citizen science is needed to be introduced to make an understanding of citizen inquiry. Citizen science is how public people engage in science with the scientist (Herodotou et al., 2014). When it was led with scientific inquiry investigation,

it becomes citizen inquiry. The idea of citizen inquiry is highlighted on public participation, which will contribute data to the scientist and involve in scientific processes – from collecting data to planning their research (Herodotou et al., 2017). Other than that, citizen inquiry allows people to work as a community and share their thoughts and knowledge on the topic people are interested in (Aristeidou et al., 2013). Many environmental problems attract citizens to conduct experiments, such as McKercher et al. (2017) and Sharples et al. (2017) use sensors to monitor the environmental problem. Forrest et al. (2019) use a citizen science program to monitor microplastics pollution.

2.3 The Role of Technologies in Citizen Inquiry and Environmental Issues

The environmental issue has become a critical topic. However, due to numerous topics in school curricula, environmental education has not been fully paid attention to (Ortiz, Conkey, Brennan, Fedynich, & Green, 2020). Shifting to citizen inquiry allows students to explore the problem with real experience by using various technologies and an online-based platform. Thus, learning activities become more community-driven and motivated (Aristeidou et al., 2013). Also, using citizen inquiry and citizen science with technology shows a positive impact on learning about an environmental issue, for example, acquiring more understanding by more involvement in authentic experience (Ellenburg et al., 2019), raising student's interests, and acting as a connection between youth and environmental responsibility (Buchanan, Pressick-Kilborn, & Maher, 2018).

2.4 Learning about Microplastics and Awareness of Environmental Problem

Microplastic acts as a threat to the environment to enter the freshwater reservoir and fish gut (Campbell et al., 2017; Forrest et al., 2019). Therefore, many studies have addressed this critical issue (Vortmann, Remy, Klasmeier, & Beeken, 2019). Replicate the microplastic experiment with low-cost equipment to generate students' engagement and make the lesson more vibrant, or Raab & Bogner (2020) proposed with the learning module, which will enable students to be more conscious about plastic in their lives and, by doing that, will eventually decrease the pollution of microplastics.

Awareness also plays a crucial part in microplastic and environmental problems. When it was looked at in literal meaning, awareness acknowledges something or understanding based on experience or information. Then, if the environmental aspect is applied, environmental awareness is the ability of a person to make a connection and have comprehension between the activities of humans and the environment (Du et al., 2018). Hassan, Noordin & Sulaiman (2010) studied that a different group of students from different areas has various levels of awareness.

3. Method

3.1 Sample Descriptions

A total of 50 pre-service teachers from the Science Department Undergraduate Khon Kaen University participated in this study. 64% of participants are female meanwhile 36% of participants are male. The range of age 20-22 years old with 48% participant in age 21, 46% in age 20 and 6 % in age 22. The participants are majoring in general science in the third year grade. The survey was conducted online using google form. Besides, we conducted the document analysis in biology skills context. The document analysis based on the biology competency (Clemmons et al., 2020).

3.2 Data Sources

3.3 Understanding Test of Microplastics and Environmental Awareness

The test was adapted from (Janoušková et al., 2020) and was translated into Thai by researchers. An experienced lecturer verified the test. The test consists of nine multiple-choice items with one score for each correct answer.

The 5-points likert scale questionnaire of environmental awareness was adapted from Eren and Yaqub (2015). Then, translated into Thai language by researchers. This questionnaire consists of 15 items scored on a five-point Likert scale in which "5" represent "Strongly agree," "4" represents "Agree," "3" represents "neutral," "2" represents "Disagree" and "1" represents "Strongly Disagree." The internal consistency of the questionnaire by Cronbach alpha is 0.81, implying that the instrument has good reliability.

3.4 Analysis Biology Competencies

There are six core competencies in this research, which are: the ability to apply the process of science (C1); the ability to use quantitative reasoning (C2); the ability to use modeling and simulation (C3); the ability to tap into the interdisciplinary nature of science (C4); communicate and collaborate with other disciplines (C5); and the ability to understand the relationship between nature and science (C6) (Clemmons et al., 2020). While the topic of microplastics consists of six subtopics: 1) what is microplastic; 2) how does microplastic come; 3) how to identify microplastic; 4)microplastic in the environment; 5) microplastic in human food and human health, and 6) reduce microplastic. In the analysis, the researcher set the learning outcome in each activity then associated it with the six competencies. The learning outcome was created based on the Thai curriculum and Indonesian curriculum, in which the curriculum only addresses the environmental issues without mentioned the microplastics. Then, integrate the learning outcome with eight steps of citizen inquiry which are "1) find my topic, 2) decide my inquiry questions or hypothesis, 3) plan my method, equipment, actions; 4) collect my evidence; 5) analyze and represent my evidence; 6) respond to my question or hypothesis; 7) share and discuss my inquiry, and 8) reflect on my progress" Sharples (2013).

4. Results and Discussion

4.1 Pre-service Teachers Understanding about Microplastics

Based on Figure 1, it can be seen that the majority of students have a better understanding of the microplastics concept. The highest score is in the effect of microplastics and reduces microplastics which is stood at 95.92 %. The findings have similar to Janoušková et al. (2020) research which is that the students generally had good knowledge of the microplastics' sources and the mechanisms of its formation. However, at the definition of microplastics, students still have difficulties in differentiating between microplastics and nano plastics; therefore, the percentage is lowest compared to other topics.

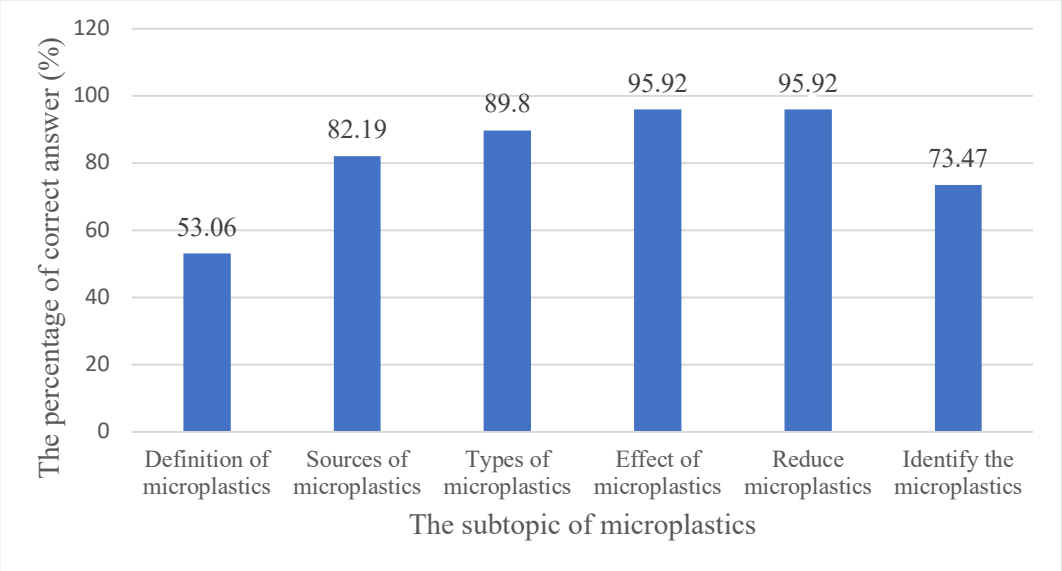

Figure 1. The percentage of the correct answer of microplastics concept.

Understanding microplastics for the pre-service teachers is categorized in the ability to understand the content knowledge, which is an essential part of TPACK skills. Although pre-service teachers has a good understanding about microplastics, measurement about TPACK skills is still needed. According to Srisawasdi (2012), TPACK could be the core attributes to influence the teaching practices for future teachers. Therefore, future research can focus on how pre-service teachers apply technology and learning strategies in the learning activities. Microplastic's measurement needs to apply in high school students considered microplastics has not been taught in schools.

4.2 Pre-Service Teacher's Environmental Awareness

Pre-service teacher's awareness of environmental issues is good, with an average of 75 %. The results indicate that pre-service teachers have good consciousness of environmental issues. As mentioned by OECD (2009), global awareness became one of the interdisciplinary themes that must be integrated into the science or another core subject. Interestingly, based on table 1, it can be seen that pre-service teacher's awareness of pollution in the air and rivers is relatively high exceeded 90%. Meanwhile, awareness of composting the food residue to become fertilizer has the lowest percentage, 55.2 %.

Table 1. *Pre-service teacher's Awareness about Environmental Issues*

ENVIRONMENTAL AWARENESS QUESTIONS	5		4		3		2		1		Average	Awareness %
	N	%	N	%	N	%	N	%	N	%		
I would avoid using plastic bags.	9	18	17	34	21	42	3	6	0	0	3.64	72.8
I prefer to use easily-soluble bags rather than plastic bags.	25	50	15	30	3	6	6	12	1	2	4.14	82.8
I throw the plastic, metal Plastic, metal and paper to separate recycling boxes	7	14	16	32	21	42	4	8	2	4	3.38	67.6
I throw the garbage to dustbins before leaving that place and not leaving any trash.	13	26	19	38	14	28	3	6	1	2	4	74.8
I read about environmental issues in the mass media	7	14	14	28	21	42	8	16	0	0	3.38	67.6
I concern about environmental problems at my place	27	54	19	38	3	6	1	2	0	0	4.4	88
I always discuss about environmental problems with my friends	9	18	16	32	23	46	2	4	0	0	3.62	72.4
I feel disappointed with air pollution	35	70	14	28	0	0	0	0	1	2	4.6	92
I feel disappointed with river pollution	36	72	14	28	0	0	0	0	0	0	4.62	92.4
I try to reduce amount of waste at home by collecting materials that can be recycled	16	32	26	52	7	14	1	2	0	0	4.06	81.2
I composting the food residue to become fertilizer	5	10	6	12	17	34	17	34	5	10	2.76	55.2
I do not use plastic bag to wrap things	4	8	3	6	25	50	15	30	3	6	2.82	56.4
I conserve the use of water supply	6	12	20	40	19	38	5	10	0	0	3.52	70.4
I deliver information on environment to my family members	6	12	14	28	22	44	6	12	2	4	3.36	67.2
I aware my responsibility towards environment	20	40	23	46	7	14	0	0	0	0	4.22	84.4
									Average		3.75	75.01

Through a good result of awareness, pre-service teachers are expected to master and transfer the knowledge and the attribute to their students. In another study, Hassan, Noordin & Sulaiman (2010) studied that even though overall of participant has a reasonable rate of environmental awareness, some aspects of the awareness are still worth consider to be raised. Moreover, a different group of students from other areas has various levels of awareness. Hence, the method of increasing environmental awareness should be implemented in another participant. Philips et al. (2018) also stated that students' awareness could be raised using citizen science as a framework.

4.3 Learning Activities to Support Biology Skills in Citizen Inquiry Condition

Pre-service teachers can arrange many activities to promote biology skills for students. The content of knowledge (microplastics) is accommodated in the Thai curriculum. Although the term "microplastics" is not mentioned in the curriculum, it is a part of environmental issues. The curriculum only addressed environmental issues. Students can inquire and discuss the environmental problem and the potential effect on natural resources and propose the solution to the problem and natural resources conservation (OBEC & IPST, 2017).

Table 2. *List of Learning Activities and Biology Skills in Each Topic*

Topics of microplastics	Learning activities	Technologies		Biology Skills
		In Class	Out Class	
What is Microplastics	Hands-on activity (to do an illuminating plastic lab)	Experiment kit Website; Video	Google Form/ NQuire toolkit	C1+C2+C4
How does microplastic come	Problem-based learning (to sort type of microplastic)	Video	Google Form/ NQuire toolkit	C1+C2
How to identify microplastic	Hands-on activity (to use a paper filter to identify microplastic)	Experiment kit Website; Video; Google Slide	Mobile App	C1+C2+C4+ C5
Microplastic in Environment	Problem-based learning and Game-based learning (to draw a pathway of microplastic in the environment)	Google Slide; Video	Digital Game	C1+C2+C3+ C5
Microplastic in human food and human health	Problem-based learning and Game-based learning (to discover the relationship between microplastic and human health)	Google Slide; Video	Digital Game	C1+C2+C5
Reduce Microplastic	Problem-based learning (to make a campaign to reduce the use of plastic)	Website; Video Google slide	-	C1+C2+C4 + C5+C6

Based on the core competencies, there are six sub-topics of microplastics in which those categories are taught in six days. Topic 1, 3, and 4 have two periods (each period is 50 minutes); meanwhile, topics 2, 5, and 6 only one period (see Table 2 & 3). Each issue has different kinds of biology skills. For example, on day 1, students will accomplish competency, called PQ-Mosi Competency, consisting of three types of competencies in the biology skills standard: the ability to do process science, quantitative reasoning,

and tap into the interdisciplinary nature of science. The competency name such as PQ-Mosi, PQ, and PQ-MosiCo is made to differentiate competency that students get in each day.

Table 3. *Design Learning Activities to Promote Biology Skills in Microplastics Topic*

	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6
1st period	What is Microplastics	How Do Microplastics come?	How to Identify Microplastics ?	Microplastic in Environment	Microplastic in human food and human health	Reduce Microplastics
2nd period						
Competency	 C1 C2 C4	 C1 C2	 C1 C2 C4  C5	 C1 C2 C5  C3	 C1 C2 C5	 C1 C2 C4  C5  C6

Competency	PQ-Mosi	PQ	PQ-MosiCo	PQ-INosCo	PQ-Co	PQ-MosiCoSS

According to Forrest et al. (2019), citizen science can be used in learning activities such as monitoring microplastic pollution in freshwater ecosystems. Even though, in this study, we only focus on designing activities on student participation. Integrating citizen inquiry and microplastics is potential learning activity to be held in the future (see Table 2). The citizen inquiry approach is suitable to be used for microplastic teaching and learning because citizen inquiry can connect the natural phenomena with the theoretical level in which students engage with the support of particular technology .

Table 2 also shows the alternative technologies that can be used in the learning activity. In this design, learning activity arranges into in-class activity and outclass activity. In the in-class activity, learning focuses on hands-on experiments. At the same time, outclass activity explores society's environmental problems using technologies such as google form, Nquire tools, mobile applications, and digital games. The role of Nquire tools, google form, and mobile application is to collect the data meanwhile the digital game for help students understand the concept how the microplastics affect human health. In addition, to help students visualize the microplastics and how does microplastics come using video.

The proposed technologies can be seen in Fig. 2. On day 1, the activity out of class is submitting samples they took in their life or environment that could turn into microplastic. They will submit the result by using Google Form or Nquire tools. On day 2, the activity out of class submitting samples of primary and secondary microplastics in the river/lake/field around their house through Google Form. On Day 3, they will use Mobile App to search for microplastics in everyday products in the outclass activity. The mobile app that can be used is the Microbeads app in which students can access freely. Then, on days 4 and 5, they will be using the digital game in the outclass activity.

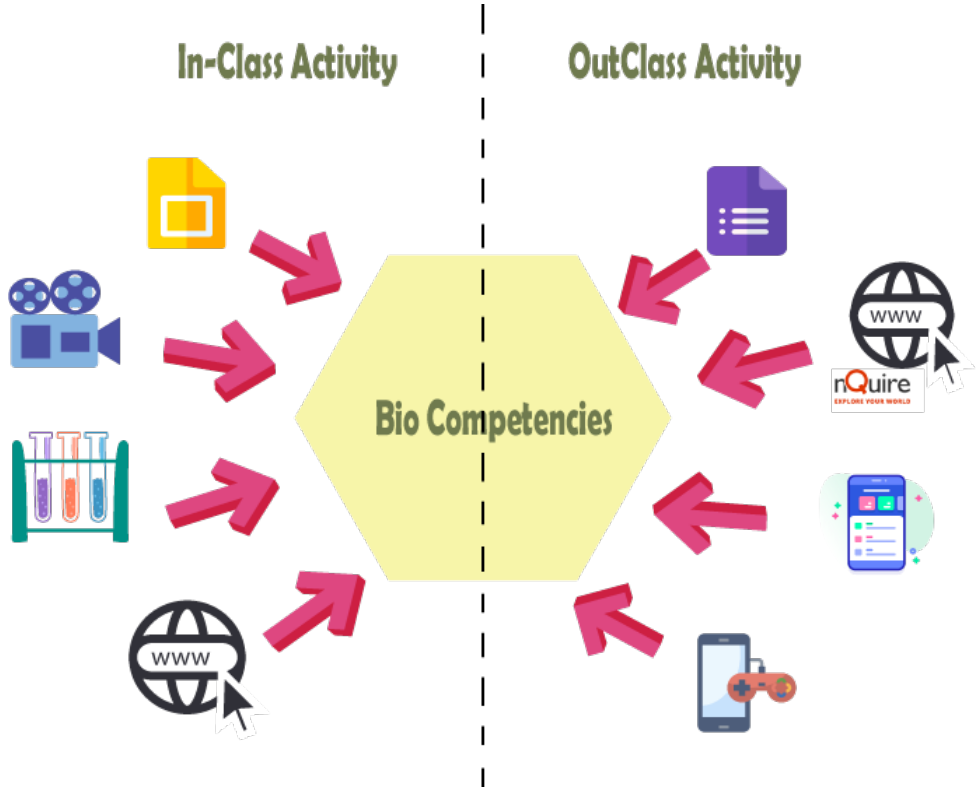

Figure 2. A proposed technology in citizen inquiry learning

5. Conclusions

Based on the main aims, the research focuses on designing activities to promote biology skills using several technologies and to know the pre-service teacher's knowledge and awareness of environmental issues. It can be concluded that pre-service teacher's understanding of microplastics and awareness of the environmental problems is good which average of the percentage 81.73% and 75 %, respectively. Learning activities to promote biology skills can be achieved using citizen inquiry and technology. A further suggestion is to develop the technology and to measure the TPACK skills of pre-service teachers.

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