Targeting Chemistry Competencies on Plastic Circular Economy with Technology-assisted Citizen Inquiry: A Proposal of Learning Matrix

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Abstract: This paper focuses on designing learning matrix activities to target core chemistry competencies. Besides, this paper will describe the role of technology in facilitating students in achieving these competencies. Based on China Senior High School Chemistry Curriculum (Wei, 2019), there are five chemistry core competencies: "1) macroscopic identification and microscopic analysis, 2) changes and equilibrium, 3) evidence-based reasoning and modeling, 4) scientific inquiry and innovation, 5) scientific attitude and social responsibility". Furthermore, due to the pivotal chemistry three representation levels (macroscopic, microscopic, and symbolic), researchers generated the sixth competency (i.e., the link between macroscopic, microscopic, and symbolic). These activities are designed for two weeks of summer camp. Many learning strategies are used in this learning matrix activities, such as interactive lessons, hands-on activities (e.g., stop-motion project), laboratory experiments, flipped inquiry-based learning, citizen inquiry, field trips, and exhibitions. Besides, various technologies are used in this learning matrix activities, such as video, mobile technology, and camera. These activities in the matrix are expected to promote students' chemistry competencies, especially on polymer, plastic, and circular economy topics.

Keywords: Learning matrix, chemistry core competencies, polymer, plastic, circular economy

1. Introduction

There is a requisite to develop students' competencies in order to respond to social needs. The latest version of the Senior High School Chemistry Curriculum (SHSCC) has been developed to respond to that challenge in China. The new curricula can be adapted by the others developing countries in the world, including Thailand. Based on China Senior High School Chemistry Curriculum (Wei, 2019), there are five chemistry core competencies: "1) macroscopic identification and microscopic analysis, 2) changes and equilibrium, 3) evidence-based reasoning and modeling, 4) scientific inquiry and innovation, 5) scientific attitude and social responsibility".

Meanwhile, there is no doubt that the development of technology has brought transformation to all subjects. In the 21st century era, digital learning has become more important in science education (Srisawasdi, Pondee, & Buntern, 2018). In terms of chemistry education, technology can support chemistry courses in various learning strategies (Nugraheni, Adita, & Srisawasdi, 2020).

According to that issue, the teacher should design particular activities to foster students' chemistry competencies. The teacher can use various technologies to help students achieve these competencies. To be used as a reference, learning activities that can help teachers teach polymer and foster students' chemistry core competencies are required to develop. These learning activities can be used as references for educators who want to teach polymer in their chemistry classroom. It provides information on how to prepare appropriate learning activities to teach polymer.

2. Literature Review

2.1 Chemistry Core Competencies

As a part of science education, school chemistry plays a prominent role in preparing students to be professional chemists and educating them to be qualified citizens (Wei, 2019). In order to respond to social change, the structure and contents of chemistry curricula have always been reconstructed (De Vos, Bulte, & Pilot, 2002).

The latest version of the Senior High School Chemistry Curriculum (SHSCC) has been developed in response to social changes in China. Based on China Senior High School Chemistry Curriculum (Wei, 2019), there are five chemistry core competencies: "1) macroscopic identification and microscopic analysis, 2) changes and equilibrium, 3) evidence-based reasoning and modeling, 4) scientific inquiry and innovation, 5) scientific attitude and social responsibility". Furthermore, due to the pivotal chemistry representation level (macroscopic, microscopic, and symbolic), researchers generated the sixth competency (i.e., the link between macroscopic, microscopic, and symbolic level). Wei (2019) stated that "the new SHSCC had provided a case for developing countries in dealing with the issues of globalization and localization in developing and designing school science and chemistry curricula." As one of the developing countries, Thailand could adapt the chemistry core competencies to respond to social change.

2.2 Students Learning about Polymer in School Setting

Based on the systematic review in the academic journals indexed by the Scopus database from 2010 to 2019, several learning strategies were employed in the learning of polymer topics, including laboratory experiment, demonstration, simulation-based learning, problem-based learning, interactive lecture, experiential learning, flipped classroom, comparative learning, heuristic teaching, example teaching, project-based learning, online earning, and application-based approach. Figure 1 displays the meta-review result.

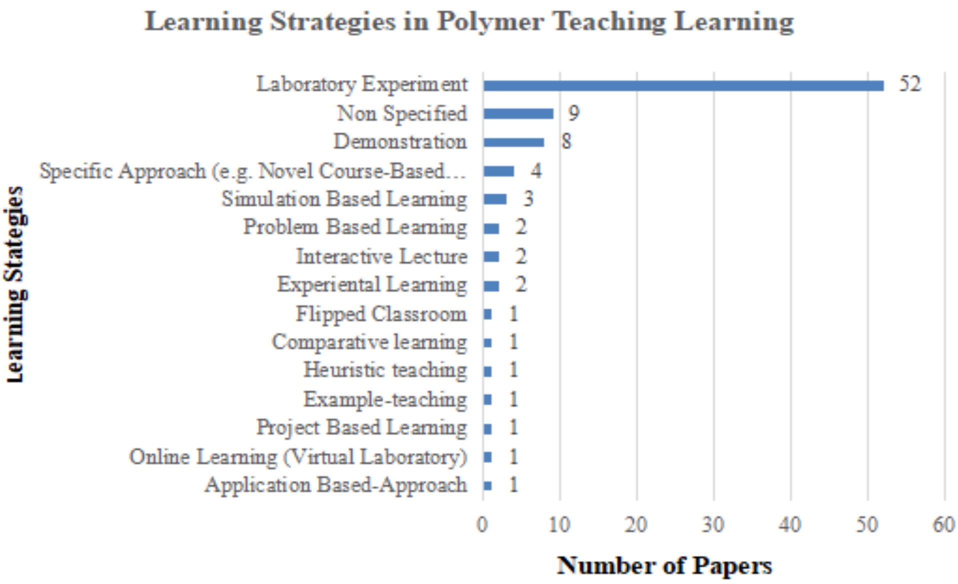


Figure 1. Learning Strategies in Polymer Teaching Learning.

As seen in Figure 1, the most favorite learning strategy in teaching polymer is a laboratory experiment. Hence, students did not obtain real-world experiences. Learning strategies such as citizen inquiry are required to implement this issue since they can bridge the theoretical level and the real world.

2.3 *Citizen Inquiry*

Sharples et al. (2013) described the term "Citizen Inquiry" as an innovative way public members can learn by initiating or joining shared inquiry-led science investigation. Furthermore, they stated that citizen inquiry refers to a combination between citizen science and collaborative inquiry learning. Additionally, Sharples (2013) proposed the syntax of citizen inquiry as follows these steps: “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”.

In a school setting, citizen inquiry is usually used to engage students with environmental issues such as tiger mosquito breeding (Perello et al., 2018), tree and bird observation on campus (He et al., 2018), plastic waste (Dean, 2020). Regarding these studies, citizen inquiry can be a bridge between the theoretical level with the real world. This learning approach can be an appropriate pedagogy to deliver polymer, plastic, and circular economy.

2.4 *The Role of Technology for Facilitating Students’ Learning*

2.4.1 The Role of Technology for Facilitating Students’ Chemistry Learning on Polymer

Based on the previous systematic review in the academic journals indexed by the Scopus database from 2010 to 2019, various technologies can support students’ learning in the topic of the polymer such as video, website, simulation, virtual laboratory, and social media (see Figure 2). As seen in figure 2, video is the most favorite technology in teaching polymer topics.

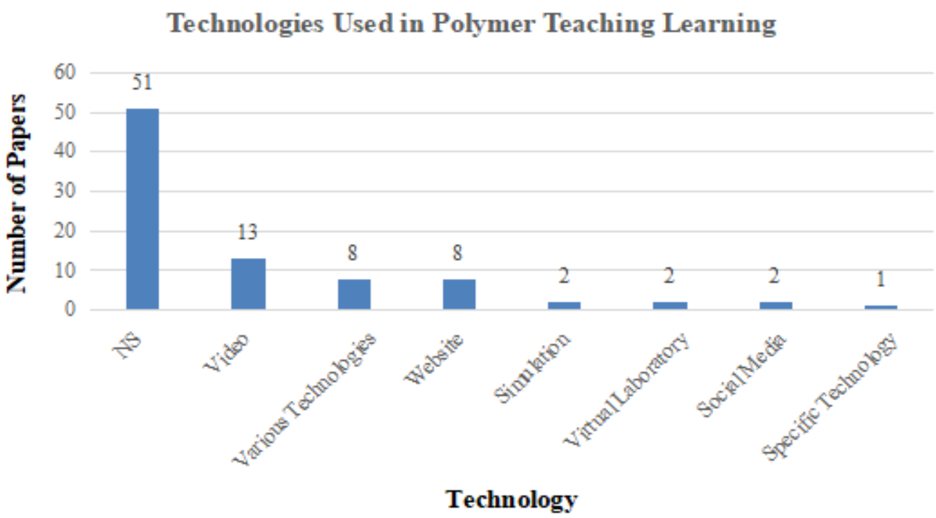


Figure 2. Technologies Used in Polymer Teaching Learning.

Educators used video in teaching polymers for many purposes. For instance, Kraft, Rankin, & Arrighi (2012) used short videos to foster students’ understanding of curved-arrow reaction mechanisms, spectroscopic methods, the polymerization of styrene, and various polymer characterization techniques. Furthermore, Shen & Tonelli (2017) used the demonstration video to explain the responses of forces slime for varying times. Meanwhile, Smith (2014) used video in his iTube, YouTube, and We Tube projects to foster students’ creative skill development and enjoyment.

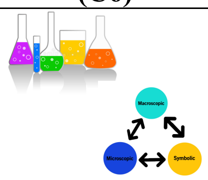
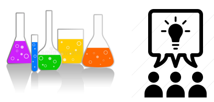
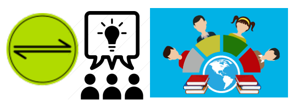
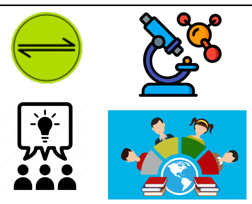
2.4.2 The Role of Technology for Facilitating Citizen Inquiry

Sharples et al. (2015) and Herodotou et al. (2018) stated that mobile devices could support citizen inquiry by engaging students with this pedagogy. For instance, the mobile device facilitates students in the process of collect data (e.g., light sensor, humidity, pressure) (Sharples et al., 2015, Herodotou et al.,2018, Aristeidou, Scanlon, & Sharples, 2020).

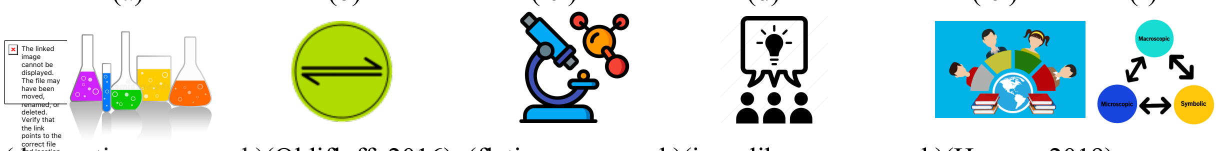
3. Designing Learning Matrix Activities of Polymer, Plastic, and Circular Economy

These activities in the matrix are expected to promote students' chemistry core competencies on polymer, plastic, and circular economy topics. Based on China Senior High School Chemistry Curriculum (Wei, 2019), there are five chemistry core competencies: "1) macroscopic identification and microscopic analysis (C1), 2) changes and equilibrium (C2), 3) evidence-based reasoning and modeling (C3), 4) scientific inquiry and innovation (C4), 5) scientific attitude and social responsibility (C5)". Furthermore, due to the pivotal chemistry representation level (macroscopic, microscopic, and symbolic), researchers generated the sixth competency/C6 (the link between macroscopic, microscopic, and symbolic level). These activities are designed for two weeks of summer camp. The learning matrix is shown below (Table 1).

Table 1. *Learning Matrix of Polymer, Plastic, and Circular Economy*

	1st Saturday	**1st Sunday**	**2nd Saturday**	**2nd Sunday**
09.00-10.30	Introduction to Polymer **(C1)**	Plastics and its utilization **(C1)**	Circular Plastic I **(C4, C5)**	Bioplastic (Formulation) **(C2, C4)**
10.30-12.00	How to identify thermosetting and thermoplastic polymers? **(C1)**	Plastic Waste Audit **(C4)**	Circular Plastic II **(C5)**	Bioplastic (Degradation) **(C3, C4)**
BREAK (12.00-13.00)				
13.00-14.30	Polymers' Properties (Traditional vs. alternative polymer) **(C1)**	What am I ? : Plastic Escape Room **(C1)**	Plastics' Recycling I **(C5)**	Exhibition **(C5)**
14.30-16.00	How are polymers formed? **(C6)**		Plastics' Recycling II **(C2, C4)**	
Learning Formula	 **Polymer Competencies**	 **Plastic Competencies**	 **Circular Economy 1 Competencies**	 **Circular Economy 2 Competencies**

(a) (b) (c) (d) (e) (f)



(dreamstime.com, n.d)(Oldifluff, 2016) (flaticon.com, n.d.)(icon-library.com, n.d.)(Hassan, 2019)

Figure 3. The Symbols of Chemistry Competencies (a) C1, (b) C2, (c) C3, (d) C4), (e) C5, and (f) C6.

3.1 Polymer Activities

Polymer activities consist of four activities. These activities will be conducted on the first day of summer camp. Each activity needs around 90 minutes.

3.1.1 Introduction to Polymer

The objective of this activity is that students will be able to explain the fundamental concept of polymer (i.e., what is polymer? kind of polymer, polymers' properties). This activity is adapted from Fagnani et al. (2020), where "think-pair-share" learning strategies will be used to establish an interactive lesson format. In addition, the video will be used as a technology to target the first competency (i.e., macroscopic identification and microscopic analysis), especially promoting students' knowledge.

3.1.2 How to Identify Thermosetting and Thermoplastic Polymers?

The objective of this activity is that students will be able to identify thermosetting and thermoplastic polymer in students' daily life. This activity is adapted from Fagnani et al. (2020). Hands-on activity learning strategies will be used in this activity. This activity will address competencies 1 (i.e., macroscopic identification and microscopic analysis), especially promoting students' skills.

3.1.3 Polymers' Properties (Traditional vs. Alternative Polymer)

The objective of this activity is that students will be able to argue controversial issues related to traditional and alternative polymers. This activity is adapted from Eilks, Marks, & Stuckey (2018). Socio-scientific issues will be employed in this activity. Meanwhile, Predict Explain Observe Explain Extend (PEOEE) will be used as learning strategies. This activity will address competencies 1 (i.e., macroscopic identification and microscopic analysis), especially promoting students' attitudes.

3.1.4 How are polymers formed?

The objective of this activity is that students will be able to link macroscopic, microscopic, and symbolic levels by creating a stop-motion video. This activity is adapted from Fagnani et al. (2020). Hands-on activity learning strategies (i.e., stop motion project) will be used in this activity. This activity will address competencies 6 (i.e., the link between macroscopic, microscopic, and symbolic).

3.2 Plastic Activities

Plastic activities consist of three activities. These activities will be conducted on the second day of summer camp. Activity 1 and 2 need 90 minutes. Meanwhile, activity 3 needs 2x90 minutes.

3.2.1 Plastic and Its Utilization

The objective of this activity is that students will be able to explain what plastic is and the kind of plastic, and its utilization. This activity is adapted from Fagnani et al. (2020) and Guedens & Reynders (2017). The "Think-pair-share" learning strategies will be used to establish an interactive lesson format. Video will be used as technology in this activity. This activity will address competencies 1 (i.e., macroscopic identification and microscopic analysis), especially promoting students' knowledge.

3.2.2 Plastic Waste Audit

The objective of this activity is that students will be able to survey to estimate plastics' utilization. This activity is adapted from the 5 Gyres Institute (2020). Citizen Inquiry will be used as a learning strategy in this activity. Furthermore, the nQuire toolkit will be employed as a technology for conducting the survey. This activity will address competencies 4 (i.e., scientific inquiry and innovation).

3.2.3 What am I: Plastic Escape Room

The objective of this activity is that students will be able to identify unknown resin plastic. This activity is adapted from Peleg et al. (2019) and the 5 Gyres Institute (2020), where a laboratory-based chemistry escape room will be employed as a learning strategy in this activity for addressing the first competency (i.e., macroscopic identification and microscopic analysis), especially promoting students' skills.

3.3 Circular Economy Activities

The circular economy consists of seven activities. This activity will be conducted on the third-fourth day of summer camp. Activity 1-6 need 90 minutes. Meanwhile, activity 7 needs 2x90 minutes.

3.3.1 Circular Plastic I

The objective of this activity is that students will be able to explain the circular plastic concept and solve the problem related to circular plastic. This activity is adapted from Dean (2020). Citizen inquiry will be employed as a learning strategy in this activity. Furthermore, video and nQuire toolkit will be employed as technologies. This activity will address competencies 4 (i.e., scientific inquiry and innovation) and competencies 5 (i.e., scientific attitude and social responsibility).

3.3.2 Circular Plastic II

The objective of this activity is that students will be able to propose a solution by creating a product to deal with single-use plastic. This activity is adapted from Dean (2020), where a hands-on activity will be employed as a learning strategy in this activity for addressing the fifth competency (i.e., scientific attitude and social responsibility).

3.3.3 Plastic Recycling I

The objective of this activity is that students will be able to explain how to turn plastic waste into valuable products by particular methods in the surrounding community. This activity is adapted from Fagnani et al. (2020) and Albright et al. (2021), where a field trip will be employed as a learning strategy in this activity for addressing the fifth competency (i.e., scientific attitude and social responsibility).

3.3.4 Plastic Recycling II

The objective of this activity is that students will be able to explain how to turn plastic waste into oil by pyrolisis and produce oil by pyrolysis. This activity is adapted from Budsaereechai, Hunt, & Ngeryen (2019). Flipped inquiry-based learning will be employed as a learning strategy in this activity. This learning strategy is adapted from Chaipidech & Srisawasdi (2018). This activity will address competencies 2 (i.e., change and equilibrium) and competencies 4 (i.e., scientific inquiry and innovation).

3.3.5 Bioplastic (Formulation)

The objective of this activity is that students will be able to produce bioplastic. This activity is adapted from Knutson et al. (2019). Flipped inquiry-based learning will be employed as a learning strategy in this activity. This learning strategy is adapted from Chaipidech & Srisawasdi (2018). This activity will address competencies 2 (i.e., change and equilibrium) and competencies 4 (i.e., scientific inquiry and innovation).

3.3.6 Bioplastic (Degradation)

The objective of this activity is that students will be able to analyze bioplastic degradation and decide the best bioplastic based on its degradation. This activity is adapted from Knutson et al. (2019). A guided-inquiry laboratory experiment will be employed as a learning strategy in this activity. This activity will address competencies 3 (i.e., evidence-based reasoning and modeling) and competencies 4 (i.e., scientific inquiry and innovation).

3.3.7 Exhibition

The objective of this activity is that students will be able to display and present a product as a solution to solve plastics' problem for saving the environment.This activity is adapted from Guedens and Reynders (2017), and exhibition will be employed as a learning strategy for addressing the fifth competencies (i.e. scientific attitude and social responsibility).

4. The Role of Technology in Learning Polymer, Plastic, and Circular Economy

In the learning matrix activities, various technologies are expected to implement. These technologies and their roles are shown in table 2.

Table 2. *The Role of Technology in Learning Polymer, Plastic, and Circular Economy*

Day	Sub-Topic	Technology Used	Role of Technology
1	Introduction to Polymer	Video	Help students understand polymer's concept, especially to visualize the structure and properties of polymers at the microscopic level.
		Camera	Help students to capture polymer in their daily life
1	How are polymers formed?	Video	Help students to link macroscopic, microscopic, and symbolic levels in the concept of polymerization
2	Plastic and Its Utilization	Video	Help students to understand plastic, especially to visualize the structure and properties of plastics at the microscopic level.
		Mobile technology (nQuire toolkit)	Help students to collect data
3	Circular Plastic I	Video	Help students to understand the concept of circular plastic.
		Mobile technology (nQuire toolkit)	Help students to collect data
3	Plastic Recycling I	Camera	Help students to capture the process of plastic recycling in students' surrounding community
3	Plastic Recycling II	Video	Help students to understand the concept of pyrolisis, especially to visualize that matter is in motion and change
4	Bioplastic (Formulation)	Video	Help students to understand the concept of bioplastic formation, especially to visualize that matter is in motion and change.

Based on table 2, video is expected to use in many sub-topics. Using video in many sub-topics of polymers is in line with the systematic review results in the academic journals indexed by the Scopus database from 2010 to 2019. The results revealed that video is the most favorite technology in the teaching polymer. Meanwhile, mobile technology will support students in collecting data in citizen inquiry. Usage of mobile technology is in line with the previous studies that stated mobile devices could facilitate students in the process of collect data in the citizen inquiry pedagogy (Sharples et al., 2015, Herodotou et al., 2018, Aristeidou, Scanlon, Sharples, 2020).

5. Conclusion

This paper shared designing learning matrix activities on polymer, plastic, and circular economy topics. Besides, this paper described various technologies to facilitate students for achieving these competencies. These activities in the learning matrix are expected to promote students' chemistry core competencies.

Since this learning matrix activity has not been implemented yet in a school setting, it could be implemented for future work. Hence, the leveraging of the implementation of this learning matrix activity can be measured empirically.

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