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Science Learning Management That Integrates Three Conceptual Levels of Chemistry about Polymer to Promote Scientific Conception Perception for Secondary School Students

Anodar Ratchawet
Faculty of Science and Technology, Chiangmai Rajabhat University, Chiangmai, Thailand

Nakharin Aiamkran
Satri Ang Thong School, Muang District, Angthong,Thailand

Sudarat Khadsai
Faculty of Science and Technology, Thepsatri Rajabhat University, Lopburi, Thailand

Thanin Intharavisit
Faculty of Education, Thepsatri Rajabhat University, Lopburi, Thailand

Yuttana Chaijalear (Corresponding Author)
Faculty of Science and Technology, Thepsatri Rajabhat University, Lopburi, Thailand
Email: Yuttana.c@lawasri.tru.ac.th

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Abstract

This study aimed to (1) design and evaluate the suitability of a science learning management plan that integrates the three conceptual levels of chemistry (macroscopic, submicroscopic, and symbolic) on the topic of polymers, and (2) examine its effects on promoting scientific conceptual understanding among secondary school students. Employing an action research methodology, the study involved 72 participants: 9 expert science teachers who assessed the instructional plan and 63 purposively selected secondary students who participated in the implementation. The intervention was structured around the QSEEE instructional model, which comprises five stages: Questioning, Searching, Explaining, Elaborating, and Evaluating. The evaluation results indicated that the instructional plan was highly appropriate. Furthermore, post-intervention assessments revealed significant improvement in students' scientific conceptual understanding, demonstrating the effectiveness of the integrated approach.

Keywords: Current Condition and Need, Happiness Farmer Field Schools, Sustainable Citizenship, Secondary School Students

1. Introduction

It is now widely acknowledged that one crucial factor driving a country's advancement towards a knowledge-based economy, both economically and socially, is having a strong foundation in science and technology. This enables the government to adapt quickly to the rapid changes of the globalized era. (National Science and Technology Development Agency, 2014) Science is the discipline that deals with the various sciences surrounding us. It plays a crucial role in daily life and all professions, as well as in technologies, tools, and products that humans use to enhance convenience in life and work. These advancements are all outcomes of scientific knowledge blended with creative thinking and other disciplines. Science helps humans develop systematic thinking, creativity, analysis, critique, and problem-solving skills. It enables informed decision-making based on diverse data and provides verifiable evidence. Science is the modern world's culture, contributing to a knowledge-based society. Therefore, everyone needs to develop to understanding of science so they can have knowledge and understanding of nature and the technologies created by humans. This enables them to use their knowledge logically, creatively, and ethically. (Kuntree Petcharatwiphat, 2007) Science is the culture of modern society, regarded as a society of learning because it helps humans develop thinking skills, capabilities in knowledge-seeking, and systematic problem-solving abilities. (Institute for the Promotion of Teaching Science and Technology, 2011) Scientific problem-solving involves applying appropriate frameworks in the problem-solving process using science as a basis to explore answers and explain various phenomena in nature. (Meng & Doran, 1993)

The subject of chemistry is a part of science education aimed at developing students' scientific literacy. In studying chemistry, students explore the nature of substances and their transformations. However, in educational practices, it has been observed that students often fail to perceive chemical changes at the molecular level. This lack of understanding impedes their learning in chemistry. Therefore, teaching and learning strategies in chemistry education (Johnstone, 1993) must be designed to align with the nature of chemistry itself. This includes conducting experiments related to substances and their transformations, explaining at the molecular level, and summarizing study outcomes using the symbolic level. In managing learning, there is a conflict with the natural way students learn. Students acquire new knowledge when sensory inputs are involved, encompassing all five senses, and this knowledge is stored in short-term memory. Students need to employ various techniques to transfer this knowledge into long-term memory. It can be observed that the nature of chemistry education, which predominantly focuses on lectures, makes chemistry a challenging subject for students.

Based on national-level educational testing data for Grade 9 students conducted by the National Institute of Educational Testing Service (NIETS), there were 665,230 examinees in the subject of Science. The national average score was 30.07 points. Specifically, in the content area of Substances and Properties of Substances, the average score was 26.03 points. (National Institute of Educational Testing Service, 2019) It can be observed that the average scores in the content area of Substances and Properties of Substances are relatively low, with an average score of less than 50%. This indicates that Grade 9 students did not perform as expected in the national-level educational testing in Science. This suggests that the Science education provided to Grade 9 students may have led to misconceptions in scientific perceptions. Consequently, this has resulted in lower-than-expected national-level educational testing scores for Grade 9 students in Science.

Upon reviewing research findings, it was found that students' misconceptions regarding the concept of polymers often cover the following content: 1) The meaning of polymers and monomers, 2) Types of polymers, 3) Polymer technologies, and 4) Environmental pollution from polymer usage. (Panee Udomphol, 2011) Teaching has been reorganized into a representative model of chemical concepts across three levels to address students' misconceptions on the topic. This approach aims to prevent students from developing misconceptions in scientific perspectives. It helps rectify conflicting teaching practices that contradict students' natural learning tendencies, potentially leading to improved national-level educational testing scores for Grade 9 students.

The nature of teaching chemistry often conflicts with students' natural learning tendencies due to its abstract content, requiring the use of Symbolic knowledge in learning. Teaching chemistry based on the three-level chemical concept framework aims to help students correctly understand the subject matter and prevent misconceptions in scientific perspectives. Understanding or misconceptions in scientific perspectives of teaching and learning can hinder students' learning. If students have misconceptions or alternative ideas diverging from correct scientific perspectives, it can impede learning because altering misconceptions can be difficult. (Wanthipha Rodraengka, 1997)

Given the low performance of Grade 9 students in national science assessments and the prevalent misconceptions in chemistry—particularly regarding polymers—this study aims to develop an integrated science learning management model based on the three-level chemistry concept framework. The goal is to enhance students' scientific understanding and correct scientific misconceptions, thereby improving science education outcomes.

Therefore, the researcher is interested in studying the integrated science learning management model based on the **3-**level chemistry concept regarding polymers to promote students' scientific understanding and correct scientific perspectives in Secondary school education. This approach aims to create a teaching and learning strategy that enhances students' accurate scientific perspectives, leading to improved national basic education examination results in science for Grade **9** students. Additionally, it will benefit teachers as they can use the study findings as guidelines to further enhance students' correct scientific perspectives in their teaching practices.

2. Methodology

2.1. The Research Model

This research is an Action Research (AR) by Inoue (2015), consisting of 4 steps: 1) Plan, 2) Act, 3) Assess, and Reflect. This model was selected to allow iterative refinement of instructional strategies in a real educational context.

2.2. Populations and Samples

The population used in the study consists of 2 main target groups: 1) Experts evaluating the instructional management plan, including professors, science teachers, and experts in science instructional management; and 2) Experimental groups using the instructional management, comprising Secondary school students. The sample size, selected through purposive sampling, consists of 72 individuals including 1) The group of experts evaluating the instructional management plan consists of 9 individuals, including professors, science teachers, and experts in science instructional management, and 2) the experimental group using instructional management comprises 63 Secondary school students.

2.3. Tools Used in the Research

The tools used to collect data consisted of 1) the assessment questionnaire for the science learning management plan that integrates three conceptual levels of chemistry about Polymer to promote scientific conception perception for Secondary school students, 2) assessment questionnaire for students' scientific perception at Secondary school. 3) Focus group discussion form.

2.4. Data Collection

Study of documentary data (Documentary Study), collecting information from documents such as books, journals, and various geographical sources related to the integration of three conceptual levels of chemistry about Polymer to promote scientific conception perception for Secondary school students. This involves gathering foundational data and using it to analyze educational issues, thereby designing learning strategies for implementation in educational development plans.

Design and Development involves designing and developing an integrated science learning plan based on three conceptual levels of chemistry about Polymer to promote scientific conception perception for Secondary school students. Evaluation of suitability is conducted by science learning management experts, utilizing assessment tools designed specifically for evaluating the appropriateness of the integrated science learning plan based on three conceptual levels of chemistry about Polymer to promote scientific conception perception for Secondary school students. The results of the evaluation and recommendations are then used to further develop the science learning plan.

Assessment involves evaluating the level of scientific perception of Secondary school students. The tools used included of scientific perception assessment form for Secondary school students and a focus group discussion form.

2.5. Data Analysis

Qualitative Data: the researchers analyzed the data according to the educational objectives using Content Analysis, derived from document analysis and interviews. This process involved summarizing issues based on data groups and analyzing the relationships between the data.

Quantitative Data: the researchers analyzed the data obtained from the assessments using statistical package software for conducting appropriate statistical analyses. This involved descriptive statistics analysis, the results were presented as mean and standard deviation.

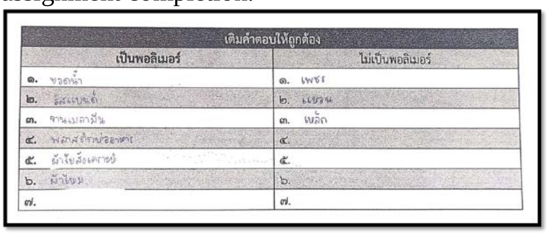
3. Results

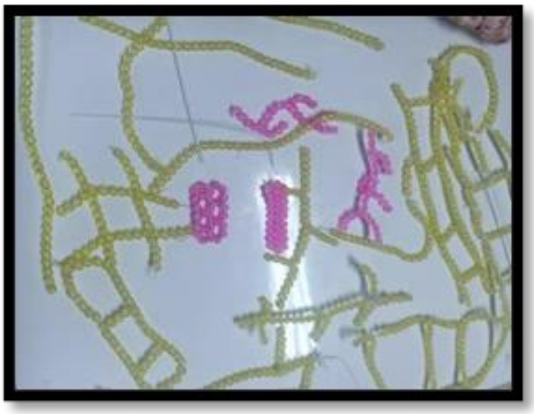
For the research at this time, the research team has classified the data obtained from the study and presented the research results according to the determined objectives. The study results can be summarized as follows:

Designing and evaluating the appropriateness of a science learning management plan that integrates three conceptual levels of chemistry about Polymer to promote scientific conception perception for Secondary school students resulted in the development of 2 learning management plans. The total teaching time required was 2 hours. The process for organizing learning activities in 5 steps, known as the "QSEEE Science Learning Management Model," consists of 1) Questioning to generate interest (Question: Q), 2) Searching and exploring (Search: S), 3) Explaining and summarizing findings (Explanation: E), 4) Elaborating on knowledge (Elaboration: E), and 5) Evaluating outcomes (Evaluation: E) are as follow.

Table 1. Details of the Learning Management Process and Example Situations in Learning Management According to the QSEEE Science Learning Management Model

Steps	Main concepts	Learning management situations observed in the classroom
Stimulate interest	The teacher stimulates student participation by emphasizing scientific questions and using them in conjunction with prior knowledge.	**The situation of learning management:** The teacher reviews students' prior knowledge by using open-ended questions to assess existing understandings and misconceptions and to generate interest in the topic of polymers as follows. Teacher: Students, please try to mention things around us that are materials. Student: I see clothes, pens, desks, and water bottles, which are materials synthesized or derived from nature.

<table>
<tr><th>Steps</th><th>Main concepts</th><th>Learning management situations observed in the classroom</th></tr>
<tr><td></td><td></td><td>Teacher: How do you think the items on the table differ in usefulness for everyday life?
Student: The water bottle is used for holding liquids with a sealed lid that allows me to carry it anywhere. Plastic wrap helps prevent dirt from getting into food. Melamine plates are sturdy and lightweight.
The learning management situation:
The teacher draws upon students' prior experiences and knowledge about polymer materials to stimulate situations in their daily lives.
Teacher: Why does a water bottle need to have properties that are rigid enough to hold liquids and withstand air pressure when taken up to the mountains?
Student: A water bottle has strong characteristics that allow it to remain intact and withstand both internal and external pressures well.
Teacher: Why does plastic wrap for food need to be flexible, clear, and resistant to heat and cold?
Student: Plastic wrap for food needs to be clear so that you can see the food inside, and it needs to be flexible so it can cover different-shaped containers and not dissolve or become rigid when exposed to heat and cold from the food.
Teacher: Why do Melamine plates have properties of strength and resistance to heat and cold, but not flexibility?
Student: Melamine plates need to be strong to support the weight of food and maintain their shape when exposed to heat and cold
From the analysis, it was found that students can integrate their knowledge, experiences, and observations of their surroundings to create new knowledge derived from the existing knowledge prompted by the teacher's stimulation on the topic of polymers.</td></tr>
<tr><td>Survey and Search</td><td>The teacher enables students to learn and acquire new knowledge that aligns with the questions, and students gain an understanding of advanced concepts in polymer chemistry.</td><td>The learning management situation:
The teacher instructs students to integrate the knowledge gained from questioning in Step 1 together with their existing life experiences into their assignments. They are tasked with applying this knowledge to separate polymers in everyday life, facilitating knowledge exchange for assignment completion.

<table>
<tr><th colspan="2">เติมคำตอบให้ถูกต้อง</th></tr>
<tr><th>เป็นพอลิเมอร์</th><th>ไม่เป็นพอลิเมอร์</th></tr>
<tr><td>๑. ขวดน้ำ</td><td>๑. เพชร</td></tr>
<tr><td>๒. ริสแบนด์</td><td>๒. แหวน</td></tr>
<tr><td>๓. จานเมลามีน</td><td>๓. เหล็ก</td></tr>
<tr><td>๔. พลาสติกห่ออาหาร</td><td>๔.</td></tr>
<tr><td>๕. ผ้าใยสังเคราะห์</td><td>๕.</td></tr>
<tr><td>๖. ผ้าไหม</td><td>๖.</td></tr>
<tr><td>๗.</td><td>๗.</td></tr>
</table>
Example of answering the polymer separation worksheet in everyday life.
From the analysis, it was found that students correctly applied their existing knowledge obtained from questioning and exchanging ideas, as well as from their everyday life experiences, to accurately</td></tr>
</table>

Steps	Main concepts	Learning management situations observed in the classroom
		separate polymers in the assignment on daily life polymer separation.
Explain and summarize the results.	Teachers and students collaborate in presenting ideas at the microscopic level and presenting ideas at the symbolic level.	**Learning situation:** Teachers have students practice group activities so that students can build evidence-based knowledge. and allow students to understand polymers at the molecular level and an explanation can be created from the polymerization reaction. In making a group worksheet on modeling the structure of polymers giving students the use of wire and beads. (representing each monomer molecule) strung together to form a polymer structure in the form of strands, branches, and reticules. **The learning management situation:** The teacher instructs students to engage in group activities to enable them to create knowledge based on evidence. Students are expected to understand polymers at the molecular level and provide explanations of polymer formation reactions. In the group assignment on "Modeling Polymer Structures," students use wires and beads (instead of monomers) to create polymer structures in linear, branched, and network forms.  Picture of linear, branched, and network polymer structures. From the analysis, it was found that students can create models of polymer structures, such as linear, branched, and network structures, using wires and beads. This process leads to the construction of molecular-level knowledge among students, derived from the evidence of model construction. It describes the characteristics and properties of polymers, as exemplified by models of linear, branched, and network polymer structures, along with group assignments on polymer structure modeling.
Expand knowledge	The teacher creates new situations beyond regular teaching to help students connect existing knowledge and generate new knowledge.	**The learning management situation:** The teacher guides students to build additional knowledge from what they have learned using questions, enabling them to apply and expand their knowledge further. Teacher: What type of polymer has properties that are rigid but can easily break? Student: Network polymer structures

Steps	Main concepts	Learning management situations observed in the classroom
		Teacher: What is an example of a polymer with a linear structure in daily life? Student: Plastic toys Teacher: What is a Polymer structure with closely packed monomers and high strength? Student: Linear structure Teacher: Which of the following items is not classified as a polymer? Student: Metal Teacher: A plastic water bottle with a linear polymer structure, what are its melting point and density like? Student: It has a high melting point and high density. From the analysis, it was found that students have integrated newly acquired knowledge by expanding upon previous stages. They have applied this knowledge in ongoing learning and teaching processes. Moreover, they have adapted this knowledge for everyday life and received guidance from instructors on newly added polymer-related topics.
Assessment process	The teacher allows students the opportunity to communicate their understanding of concepts and explain the reasons and outcomes of their conclusions, fostering a process of self-assessment of the students.	**The learning management situation:** The teacher collaborates with students to summarize the knowledge learned today. The teacher selects a representative student or volunteers one to summarize the results on behalf of the class, and then asks the students to collectively explain the findings using the knowledge they have learned. Teacher: Let's summarize what we've learned today. Who can summarize as a representative to answer? Student: What we learned today is about polymers in everyday life. Polymers are large molecules made up of many repeating units called monomers, which come together through chemical reactions. These polymers have different properties depending on their structure. They are formed through two types of reactions including condensation polymerization and addition polymerization. Polymers can have linear structures, branched structures, or network structures. From the analysis, it was found that the students have acquired accurate knowledge according to the content about polymers. Each student can summarize the knowledge they have learned as their answer, and they have developed a personal understanding of long-term memory.

Figure 1. QSEEE Science Learning Management Model
Resource: researcher (2025)

Then, the researcher integrated the science learning management model that integrates three conceptual levels of chemistry about Polymer to promote scientific conception perception for Secondary school students to experts in science learning management evaluated the appropriateness, and the results are as follows.

Table 2. Assessment Results of Science Learning Management Plan That Integrates Three Conceptual Levels of Chemistry About Polymer to Promote Scientific Conception Perception for Secondary School Students (N=9)

No.	Assessment list	$\bar{x}$	SD	Results
1	A science learning management plan to promote scientific conception perception.	4.44	0.73	High
2	Learning management plans to promote awareness of the importance of science learning in students' daily lives.	4.89	0.33	Highest
3	Learning management plans to promote understanding of the diverse contexts of science learning management according to global societal situations.	4.33	0.87	High
4	Learning management plan to promote 21st Century skills.	4.33	0.87	High
5	Learning management plans to provide opportunities for students to learn through real-life practice.	4.44	0.73	High
6	Learning management plan to promote scientific literacy.	4.67	0.71	Highest
7	Learning management plans to promote meaningful learning.	4.33	0.71	High
8	A learning management plan includes examples or uses a variety of learning materials.	4.67	0.71	Highest
9	Learning management plans to promote effective knowledge and understanding.	4.44	0.73	High
10	Learning management plans to promote competencies in applying digital technology for learning.	4.78	0.44	Highest
	Overview of assessment results	4.53	0.68	Highest

Table 2, shows that integrating three conceptual levels of chemistry about Polymer to promote scientific conception perception for Secondary school students, is highly suitable ($\bar{x}$ = 4.53, SD = 0.68). When considering each item, the integration of three conceptual levels of chemistry about Polymer to promote scientific conception perception for Secondary school students is found to be most suitable including of Learning management plan to promote awareness of the importance of science learning for students' daily life ($\bar{x}$ = 4.89, SD = 0.33), Learning Management plan to promote competencies in applying digital technology for learning ($\bar{x}$ = 4.78, SD = 0.44), Learning management plan to promote scientific literacy ($\bar{x}$ = 4.67, SD = 0.71), and Learning management plan includes examples or uses a variety of learning materials ($\bar{x}$ = 4.67, SD = 0.71), respectively.

Evaluating the impact of a science learning management plan that integrates three conceptual levels of chemistry about Polymer to promote scientific conception perception for Secondary school students, the researchers found the following results.

Table 3. The Level of Scientific Conception Perception for Secondary School Students (n=63)

No.	Assessment list	$\bar{x}$	SD	Results
1	The students have knowledge and understanding of the meaning of polymers.	4.50	0.59	Highest
2	The students have knowledge and understanding of polymer formation reactions.	4.80	0.56	Highest
3	The students have knowledge and understanding of the structure and properties of linear polymers.	4.73	0.59	Highest
4	The students have knowledge and understanding of the structure and properties of branched polymers.	4.60	0.63	Highest
5	The students have knowledge and understanding of the structure and properties of network polymers.	4.60	0.35	Highest
6	The students have scientific thinking skills.	4.80	0.41	Highest
7	The students have scientific literacy.	4.60	0.63	Highest
8	The students have been reinforced in their learning skills for the 21st century (21st Century Skills).	4.47	0.74	High
9	The students generate critical questions to facilitate discussion and exchange of ideas.	4.70	0.59	Highest
10	The students can apply the knowledge they have gained to their daily lives.	4.60	0.74	Highest
	Overview of assessment results	**4.64**	**0.58**	**Highest**

Table 3, shows that Secondary school students have the highest level of scientific conception perception of polymers ((x)̅ = 4.64, SD = 0.58). When considering the findings per item, students reflected the highest assessment results in the top 3 rankings including the students who have knowledge and understanding of polymer formation reactions ((x)̅ = 4.80, SD = 0.53), The students who have scientific thinking skills ((x)̅ = 4.80, SD = 0.41), The students have knowledge and understanding of the structure and properties of linear polymers ($\bar{x}$ = 4.80, SD = 0.56), respectively. From group discussions with students, they reflected that this learning management helped them gain good knowledge and understanding of polymers. It also helped them understand chemical structures and symbols effectively in their learning.

4. Discussion

Designing and evaluating the appropriateness of a science learning management plan that integrates three conceptual levels of chemistry about Polymer to promote scientific conception perception for Secondary school students resulted in the development of 2 learning management plans. The total teaching time required was 2 hours. The process for organizing learning activities in 5 steps, known as the "QSEEE Science Learning Management Model," consists of (1) Questioning to generate interest (Question: Q), (2) Searching and exploring (Search: S), (3) Explaining and summarizing findings (Explanation: E), (4) Elaborating on knowledge (Elaboration: E), and (5) Evaluating outcomes (Evaluation: E). This study designed and evaluated a science learning management plan integrating three conceptual levels of chemistry—macroscopic, microscopic, and symbolic—focused on polymer education. Implemented through the QSEEE model, the plan promoted conceptual change and scientific perception among secondary school students. The positive evaluation outcomes align with constructivist theories (Piaget, 1986; Novak, 1993), emphasizing the role of prior knowledge and active engagement in developing scientific understanding. Furthermore, the model facilitated the correction of misconceptions and the construction of meaningful knowledge, as supported by Hewson & Gertzog (1983).

Evaluating the impact of the science learning management plan that integrates three conceptual levels of chemistry about Polymer to promote scientific conception perception for Secondary school students, it was found that after implementing this approach, students achieved the highest level of scientific perception. This aligns with the theory of meaningful learning proposed by Novak, J. D. (2002), which suggests that learning where the teacher explains what needs to be learned, informs the students, and they listen with understanding involves students seeing the relationship between what they learn and the intellectual structures stored in their memories. They can then apply this knowledge in the future. This aligns with Bruner's (1960) theory of intellectual development, which proposes that learning occurs when individuals can construct a vision and organize the structure of knowledge to relate and align with intellectual development. If students can connect new knowledge or new perspectives with existing knowledge, they can learn meaningfully and apply their knowledge in the future. This is especially true when learning starts from familiar topics or from students' daily life experiences, such as learning from the environment in which students live. Due to the linkages made between newly learned information and existing knowledge or experiences, students can better solve problems, particularly when these situations are close to their immediate context. This approach aligns with the Ministry of Education's guidelines (2017), which set out the content and learning standards for the Science and Technology learning area (revised edition 2017) by the Basic Education Core Curriculum, Buddhist Era 2551. The aim of teaching and learning science under this curriculum focuses on linking knowledge to processes, emphasizing essential skills in researching information and generating diverse knowledge through various investigative methods. It also aims to solve a variety of problems according to the students' design throughout the learning process, engaging them actively at every step and involving hands-on activities to ensure a genuine understanding of science.

5. Conclusion

Examining the integrated science learning management model based on the 3-level chemistry concept regarding polymers to promote students' scientific understanding and correct scientific perspectives in Secondary school education. This approach aims to create a teaching and learning strategy that enhances students' accurate scientific perspectives, leading to improved national basic education examination results in science for Grade 9 students. Additionally, it will benefit teachers as they can use the study findings as guidelines to further enhance students' correct scientific perspectives in their teaching practices.

6. Suggestions from Future Research

6.1. Suggestions for Implementing Research Results

Science teachers should understand the process of implementing the science learning management plan that integrates three conceptual levels of chemistry about Polymer to promote scientific conception perception for Secondary school and adapt it to fit the context of their educational institution.

The school should plan teaching activities that focus on enabling students to engage actively in activities that effectively enhance their understanding.

The appropriateness of a science learning management plan that integrates three conceptual levels of chemistry about Polymer to promote scientific conception perception for Secondary school students in a team teaching.

6.2. Suggestions for Next Research

A science learning management plan that integrates three conceptual levels of chemistry about Polymer to promote scientific conception perception for Secondary school students in an online classroom.

To expand the appropriateness of a science learning management plan that integrates three conceptual levels of chemistry about Polymer to promote scientific conception perception for Secondary school students in other grade levels, and to develop and cover basic educational levels.

Enhance the integrated appropriateness of a science learning management plan that integrates three conceptual levels of chemistry about Polymer to promote scientific conception perception for Secondary school students in other content.

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