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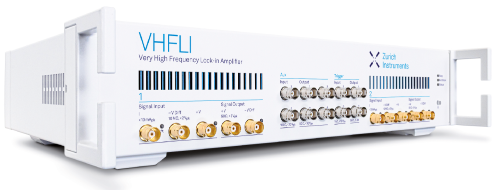

# The Development of STEM Lesson Plan on Design Thinking about Chocolate Consumer Need

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**Abstract.** The paper clarifies the process and content of STEM lesson plan development for Grade 8 students who are studying in Thailand school. The strategy employed to create STEM activity is design thinking, double diamond, compose of 5 phases; Empathy, Define, Ideation, Prototyping and Testing. The story about chocolate consumer was provided in order to engage students to identify the problems and develop solutions. Grade 8 students need to practice knowledge about boiling and melting point, latent heat, and other knowledge in order to develop solution through process of design thinking. The unit clarifies the scenario of lesson plan how to enhance students to develop prototypes regarding students' understanding about problems and empathy. Students may apply STEM knowledge for designing the packages, chocolate ingredients, and others.



## INTRODUCTION

In Thailand, STEM education has been pushed as a national strategy in an effort to meet the Thailand 4.0 objective. Because it is simple to associate STEM with a wide range of industries, including information and communications technology, the medical industry, and sustainability advancements, it may be the most representative educational reform agenda. The development of STEM literacy and workforce preparations. All students should receive STEM education because they need to engage with the natural and physical world with at least some STEM-related information, abilities, and attitudes. STEM education should not solely target students who plan to pursue STEM occupations. STEM concepts, skills, methods of thinking, 21st skills, and attitudes toward STEM occupations are all part of the preparation for the STEM workforce. [1], [2].

The idea of STEM education encompasses a wide range of subjects and methods. According to educational literature, STEM can be transformed into a multidisciplinary learning approach that can be used to incorporate knowledge from the various STEM subjects into current science, technology, engineering, and math instructional programs using project-based learning, engineering design-based studies, or problem-based learning strategies. The improvement of the teaching of distinct disciplines, notably those of science and mathematics, has received a lot of attention in policy discussions of STEM. There has been a major push for STEM education in Thailand. The efforts to train STEM teachers across the country have been promoted by the government organizations. Many organizations have offered the STEM professional development initiatives for in-service teachers [2], [3], [24], [25], [26].

STEM education has emphasized on implication for careers need or problem solving as quality citizen which combine knowledge and skills through practice. Teaching and learning STEM will be triggered through real-world problem solving [4], [27], [28], [29]. According to Moore et.al. [5] STEM focuses on the teaching and learning of material and processes, academic knowledge from science and/or mathematics, and engineering procedures that are

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applicable to technology. Teaching and learning in STEM education are centered on procedures that can be utilized to structure student participation. Students will learn not just crystalized knowledge but also the crucial fluid and soft skills they will need in the future through the process of integrating knowledge into practicing tasks; it is not only teaching about content-based curriculum but also procedural knowledge [6], [30] [31].

The point is that STEM education should emphasize method rather than content. He emphasizes the importance of STEM education when learning occurs through process activities; nevertheless, content can be applied through situational activities. Concentrating on process tasks will also allow students to learn from failure, which may take some time. This indicates that student centers are important for STEM education. This could result in a wide range of STEM teaching and learning activities. In order to improve students' learning in STEM education, activities must involve students in a STEM process and move students back and forth between their thinking and doing [7].

Crystalized information is not enough for a successful transition of students into the skilled workforce, referring to the major goal of STEM education, preparing skillful workforce or career needed. Thinking skills (e.g., creative, decision-making, problem solving, reasoning, and ability to learn), personal qualities (e.g., responsibility, self-esteem, social, self-management, integrity, honesty), and workplace competencies (ability to allocate resources, interpersonal skills, and the ability to acquire and use information and work with technology) are required for students [8], [9], [10], [32], [33]. Partnership for 21st Century Skills suggested three categories of skills for the students. These included 1) Learning and Innovation Skills, 2) Information, Media and Technology Skills, and 3) Life and Career Skills [9].

It is believed that the objective of schooling is to prepare students to meet society's demand [11] and this allocated with main aim of STEM education. According to Brandt [11], an effective instructional approach must ensure that students use skills to gain knowledge rather than memorize knowledge. Educators have agreed that students must learn 21st century skills in order to qualify for citizenship [12]. However, Kay [12] also notice that There is a lack of integration of 21st century skills into standards, education, and professional development for teachers. Measures of school success in K-12 settings tend to stress academic knowledge and do not reflect other vital abilities.

Regarding the national science curriculum standards in Thailand, science is the principal subject for basic education. Therefore, all learners from grade 1 to grade 12 are offered science content organized from simple to more complex for different grades. The subject matters in science were divided into 8 areas, basic and advance science, the basic science is implemented to grade 1 to grade 9 students, and the advance science is implemented to grade 10 to grade 12 students who want to continue further in science career. The basic science comprises of 4 areas 1) life science, 2) physical science, 3) earth science and astronomy, and 4) technology. While the advance science comprises of 1) biology, 2) physics, 3) chemistry, and 4) earth, astronomy and space [13].

To be effective, science instruction in the classroom today and in the future must teach students to manage their thought processes. In order to improve pupils' capacity for critical thinking and problem-solving, thinking skills may be addressed. Students can hone their critical thinking abilities in relation to societal issues. Students are introduced to the integrated concept of science, technology, and society (STS), which teaches scientific knowledge by selecting the best course of action to take in order to solve a problem. Teaching science improves students' comprehension of the subject matter while also fostering their ability to think critically. Science fosters the development of critical thinking abilities and is about the real world. In the first declaration, conceptual knowledge is addressed. It is thought that youngsters may be able to comprehend and explain happenings in their environment if they understand specific scientific concepts. The second statement places an emphasis on procedural expertise. It serves as an example of how science is important for children's general skill development, which is needed in a wide range of contexts [14], [15], [35].

Memorization learning and material coverage are frequently emphasized in traditional science teaching methods in science classrooms [14]. Therefore, the goal of this project is to create a lesson plan for students that uses design thinking to engage students in the learning process rather than simply teaching them scientific information to memorize. It is anticipated that students would be able to acquire scientific concepts through practical processes through the use of activities created using the design thinking technique.

## Design thinking as STEM pedagogy

Design and design thinking research is not new, particularly in engineering. However, the concepts of design and design thinking continue to be interpreted differently in different professional sectors. Design in business management, for example, generally entails deliberate and meticulous thinking and preparation in order to be creative and inventive, but design in engineering can sometimes be routine and taken for granted. Design research in education demands for theory-based interventions that can yield results that are relevant and documentable to a specific real-world situation.

The ambiguity around the meanings of design and design thinking has historically made it difficult to operationalize design concepts for curriculum and education, especially in the field of engineering. Engineering education in universities, for example, has developed from a "engineering science" approach to reflective practices typified by project-based learning (PBL) and cornerstone courses [20].

It is assumed that design thinking toolkits are used in most innovation processes. Design thinking is also thought to represent an innovative, human-centered approach to problem-solving as a way of thinking that leads to transformation, evolution, and innovation to new forms of living and new ways of managing business. Design thinking is assumed in the context of education to be a complicated thinking process of conceptualizing new realities, indicating the entry of design culture and its approaches into disciplines such as business innovation. The term design thinking, specifically the combination of the words "thinking" and "design," refers to the ability to apply design tools to problem-solving contexts. Design Thinking has evolved into a useful tool set for any innovation process, combining the creative design approach to traditional thinking, which is based on planning and analytical problem solving [17].

Fundamental characteristic of design thinking relies on the designer's capacity to consider human's needs and new visions of living well (human-centerd approach), available material and technical resources, and the constrains and opportunities of a project [18], [34]. Moreover, another important component of design thinking is that it allows researchers and end users to collaborate through framing problems and test solutions, using participatory processes.

The "double diamond" is a well-known and established expression of design thought. The double diamond is often defined as having five phases that are applied iteratively. Diverging and converging phases separate the five steps, with diverging phases broadening viewpoints and converging phases increasing focus. Five steps are commonly defined within these double diamonds. (1) Empathy: the point of view of the user is elicited. (2) Define: Knowledge about the user is distilled and formulated as specific needs, wants or requirements (problem definition). (3) Ideation: ideas for solutions are formulated based on the specific needs and requirements one is aiming to satisfy. (4) Prototyping: ideas are implemented in first stage products or services. (5) Testing: potential users and other relevant stakeholders test and provide feedback on the prototypes. These five steps are iterative, and the process may be partially or completely revisited several times [19], [20].

However, tackling problems in a given situation always involves limits. Thus, designers must convert their creative ideas into real prototypes in order to verify whether such ideas work and address the problem within the specified restrictions. This is possible through prototype testing. This method is frequently iterative until designers archive a solution to the identified challenge [23].



## METHODOLOGY

This research has attempted to illustrate circumstances of process and conception on the development of thermal conductivity of materials lesson plan referring to STEM approach employing design thinking for primary students. Qualitative approach has been considering as an idea and methodology to clarify the evaluation and process of development STEM education lesson plan for primary students. The lesson plan was developed through expert panel discussion in the Khon Kaen University professional learning community (KKU PLC).

### Participants

Participants in this study included members of KKU professional learning community addressing in the part of planning the design thinking of STEM lesson plan. The members included a pre-service science teacher and five expert panel committees. The five STEM education experts included (1) one male and two female experts who has been working as science educator at Faculty of Education, Khon Kaen University for about 10 years, and (2) two female experts who has been working as lecturers at Faculty of Education, Phuket Rajabhat University for 5 years.

### Method of inquiry

This paper will clarify only the part that we have done in the planning process through KKU PLC. The thermal conductivity of materials STEM Education Lesson plan for Grade 8 students was initially designed. Design thinking was addressed as pedagogical knowledge for the topic. The lesson plan will begin by engaging students via the chocolate story clip. The chocolate story is about what we should do next when people was disappointed by a melting chocolate bar (https://www.youtube.com/watch?v=M4iLkzVUXMo&t=4s ). This clip will engage students to empathy and understand some problems. Student empathy and definition of this story may allow Grade 8 students need to practice knowledge about boiling and melting point, and latent heat, and other knowledge in order to develop solution through process of design thinking. The unit clarifies the scenario of lesson plan how to enhance students to develop prototypes regarding students' understanding about problems and empathy. Students may apply STEM knowledge for designing the packages, chocolate ingredients, and others.

Indicators in Thailand science content standard intend students to comprehend physical property of materials such as thermal conductivity of materials. Students are expected to identify thermal conductivity of materials. Each material obtains different physical property. Nature of heat will transfer from higher temperature area to lower temperature area. Thermal conductivity is a kind of heat transfer via particle of materials from the area that obtain higher temperature to the area that has lower temperature. Particle of materials in thermal conductivity is addressed in solid.

This lesson plan aims to design for $8^{th}$ grade students, after thermal conductivity of materials STEM education lesson plan was designed, then, expert panel discussion on revising STEM education lesson plan was organized for two rounds. The issues of revising STEM education lesson plan were collected through the report of expert suggestion on expert panel discussion. The suggestion then was categorized to develop assumptions for further revising lesson plan.

## FINDING

The findings were divided into two parts. The first section will provide assumptions of revising the thermal conductivity of materials STEM education lesson plan. Second, the section will provide the revised STEM lesson plan.

### Assumptions of revising the substances separation STEM education lesson plan

Assumptions of revising chocolate STEM education lesson plan were categorized through expert panel discussion. The assumption of revising the lesson plan could be clarified as following issues.

The committee suggested for improvement the lesson plan as follow.

1. Thinking about how to provide some scaffolding questions for enhancing students to find empathy or understanding of the problems related to the chocolate situations.

2. In the test part, the teacher should engage students to evaluate prototype with scientific instrument and scientific explanation. A common instrument measuring temperature is thermometer, rather than feel temperature, thermometer is common tool to measure temperature.

3. Apart from considering different types of material when design packaging or chocolate ingredients, teacher should raise students' awareness that thickness affect the effectiveness of protecting from heat transfer as well.

### Revised the STEM lesson plan on design thinking about chocolate consumer need

Regarding on the expert panel discussion, the revised STEM lesson plan on design thinking about chocolate consumer need was organized. The learning activities were designed aligned to Thailand content standard and based school context. Normally, science subject is allocated 3 periods a week. One period is about 55 minutes. In Thailand school context, the science time table is organized for two sessions including session of one period and another session of two periods. Based on Thailand curriculum and school context, the lesson plan of chocolate STEM education was provided into 4 lesson plans as showed in the Table 1. The first lesson plan will spend time about 55 minutes. It provides the activities regarding on two stages of design thinking process including empathize and define. The second lesson plan will spend time about 110 minutes. It provides the activities regarding on stage of ideate. The third lesson plan will spend time about 55 minutes. It provides the activities regarding on two stages of design thinking process including ideate and prototype. The fourth lesson plan will spend time about 110 minutes. It provides the activities regarding on two stages of design thinking process including prototype and test.

**TABLE 1**: Overview of four lesson plans and stages of design thinking process

| Lesson plan | Stages of design thinking process |
|---|---|
| Lesson plan 1 (55 minutes) | Empathize and Define |
| Lesson plan 2 (110 minutes) | Ideate |

| | |
|---|---|
| Lesson plan 3 (55 minutes) | Ideate and Prototype |
| Lesson plan 4 (110 minutes) | Prototype and Test |

The revised the STEM lesson plan on design thinking about chocolate consumer need is highlighted as the table 2. In order to clarify clearly for what kinds of activities for design thinking process, the table 2 will explain the activities regarding each stage of design thinking process rather than each single lesson plan.

**TABLE 2:** STEM lesson plan on design thinking about chocolate consumer need

| Stage | Activity |
|---|---|
| 1. Empathise (lesson plan 1) | 1. Watch the Hug-Phaeng Chocolate clip (https://www.youtube.com/watch?v=M4iLkzVUXMo&t=4s )<br>This clip is about a boy who buys a chocolate bar and then takes it back home for his sister. Unfortunately, the chocolate is melting, when he give it to his sister.<br>2. Students do task 1 that is about giving reflection on the Hug-Phaeng Chocolate clip by completing the Google forms. The Google forms asked the following questions in order to regulate students' reflection. These included:<br>1) If you are a boy in this clip, how will you feel?<br>2) If you are a girl in this clip, how will you feel?<br>3) If you are the owner of chocolate company, how will you feel and what will you do next?<br>4) Have you ever seen the situation like in this clip? Why does the chocolate melt?<br>3. Students do task 2 in order to enhance students to develop empathy and framing the problems related to chocolate clip. The task 2 asked that "if you are working at a chocolate factory, what will you do that related to the issues based on the situation of task 1. To clarify some possible solutions, you may answer following questions.<br>1) Based the clip, what is a point of problem that will be generated a possible solution?<br>2) According to the problem, who should be the target group that you will find the solution for?<br>3. Clarify information of target group<br>• What is the motivation related to the target group?<br>• What are the goals related to the target group?<br>• What will be the factors of failure relate to the target group?<br>• What is your worry related to the target group?<br>• What are the needs to do for target group? |
| 2. Define (lesson plan 1) | The define mode helps to give clarity and focus to the entire design process. The main goal expectation of design is to draft a viable and meaningful problem statement. The task 3, therefore, will be provided in order to enhance students to reach the specific point of view. The task 3 provided the following questions:<br>1. Based on your understanding of target group, list what you should do for develop a possible solution. List what to do from most important to less important<br>2. According to your list of what to do, please frame to design a possible solution. You may answer the following questions:<br>• What is the name of your project?<br>• What is your target group?<br>• What are the needs to do for the project?<br>• What are the risks of processing the project? |
| 3. Ideate (lesson plan 2) | In order to enhance student to provide students' widest possible range of ideas for generating ideas, the scientific knowledge and others were provided:<br>- review definition of melting point and boiling point<br>- classifying the substances by melting point and boiling point<br>- do experiment of comparing about melting point of pure substances and compounds (e.g. compare graph of Naphthalene melting point and benzoic acid naphthalene melting point)<br>- do experiment of heat and the change in state of matter<br>- develop the definition of latent heat |
| Ideate (lesson plan 3) | Brainstorming a variety of ideas by the students and to suspend judgment is the challenge when ideating.<br>Task 4: brainstorming for possible and impossible ideas, advantage and disadvantage, fun and creativity related to task 3 |
| 4. Prototype (lesson plan 3) | The mode of prototype is the iterative generation of artifacts, volition, guideline, technics, system, or anything. Students do task 5 and 6. |

| | | |
|---|---|---|
| | | Task 5: list solutions during brainstorming<br>Task 6 (homework): draw prototypes and test framework (e.g. a sketch model, experiment designs, or a cardboard box) |
| | Prototype (lesson plan 4) | Hand on activity for prototyping and testing regarding on task 6. |
| 5. | Test (lesson plan 4) | Present what students learned through prototyping and testing. They could share from what better to fail early, what the test gave feedback to prototype, or what they go through the prototyping. |

The first stage (empathize) engage students with cooking situation that expect to relevant students with the content. The cooking situation was selected to trigger the problem, as it is believed that students might see this situation common and relate to their situation in everyday live. This situation might raise awareness of students about thermal conductivity.

In define stage, little girl's need about pot-holder was addressed as, normally, when we think about pot-holder, apart from protecting hand from heat transfer, we tend to consider whether it is easy to use and other perspective effect the utility.

The Ideate stage, teacher attempt to engage student with scientific concept related to decision making the material using to make pot-holder. Besides that teacher also engage student to think about others factors that relate to design pot-holder regarding little girl's requirement.

The prototype stage, teacher ask student to choose material to protect hand form burning of touching hot metal pot. This stage students will arouse to relate thermal conductivity of material concept with their decision making selecting the material. In the design process, students would have to engage other knowledge such as friction force concept to explain the design of pot-holding and some other creativity relate to arts.

The test stage in this lesson plan attempt to engage students with engineering process mindset. Students are required to consider the utility of prototype regarding their design and explain the utility of prototype from scientific evaluation from thermometer.

## CONCLUSION

This STEM lesson plan provide the idea of STEM lesson plan development employing design thinking strategy as pedagogy to instruct the activity. From this lesson plan, it is believed that the design thinking is appropriate to engage young children with STEM education and engineering design process. As first stage of design thinking arouse students to design activity, pot-holder, with storyline situation, hand burning from touching the hot pot. The awareness of thermal conductivity of material raised from this situation and arouse caution from students in the situation where they need to encounter with thermal conductivity of material. This situation believed to be wise situation relate to common phenomena occur in students everyday live which expect to arouse students with empathy in the situation and human's need. The empathy of human's need could convey student enthusiasm to the activity designing pot-holder.

Throughout considering of designing process, teacher attempt to provide the opportunity for students to engage scientific concept, thermal conductivity of materials, with the design of pot-holder. Students need to consider about the material that could resist from heat transfer which could protect hand burning from heat transfer from hot pot to hand. Beside that some other scientific concept such as friction force for the utility when holding the pot, the idea of arts in designing the pot-holder.

In addition, teacher attempt to engage students to engineering design mindset in the process of testing the utility of prototype employing scientific instrument, thermometer, to measure the temperature ensuring the utility of prototype regarding user's requirement.

The design thinking and this lesson plan is believed to gear students' interest toward mindful career being innovator as the activity such as encourage students consideration about human's need into the design, engage students with innovation design, arouse engineering design mindset. These activity involve student with such skills such as critical think, creative thinking, collaboration, and communication skill and these skills is claimed as skills for career needed in the 21$^{st}$ century skills of being quality citizen.

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