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Research article

The development of learning innovation to enhance higher order thinking skills for students in Thailand junior high schools

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ABSTRACT

The research aims to design and develop learning innovation to enhance higher order thinking skills for students in Thailand junior high schools. The design development research model of Richey and Klien (2007) is used and divided into two phases: (1) to design and develop innovative learning and validate of its quality based on the interviews and survey from 13 experts, 10 teachers and 30 students, and (2) to test the tools' validity by three experts and 153 students from five junior high schools at five provinces in Thailand. The findings indicate that analytical thinking, creative thinking, problem-solving thinking and critical thinking skill are developed by researchers, and experienced and practiced by learners in their lessons. The higher order thinking skills of learners after experiencing the learning innovation have a higher average score than the previous one. Following the students' perspectives on the learning innovation, 1) The design of content is in line with students' knowledge levels, easy to understand, and enable to connect science contents to their daily life. However, some contents cannot fully cover into all classroom lessons; 2) Multimedia. A navigation design is easy for students to find information and direct to their needs. The icon symbols could hint the meaning of various information sources and have links to these sources. Also, multimedia could considerably explain scientific processes and help students understand better; 3) The design of problem scenarios supports easier connection to the daily life. In addition, using videos as a learning resource could suitably illustrate scientific process, and improve communicative and collaborative skills in problem solving.

1. Introduction

The rapid development of information communication and technology has changed and affected the human learning in the 21st century. The learning management model must be adjusted in accordance with the current society. The rapid and continuous movement and change in many areas have taken the world into a globalization era and a knowledge-based society (Bureau of International Cooperation, Thailand, 2011). A national economic and social development plan on developing people to a sustainable learning society to support free trade opening of Thailand (Office of the National Economic and Social Development Council, 2016) indicated that learning in the 21st century has to transcend "subject matter" to learning. The teacher would design learning to train themselves to be a coach and facilitate in the problem-based learning of students.

The assessment results of the PISA 2015 found that the science average point of Thailand students was lower than the Organization for Economic Co-operation and Development (OECD) average (OECD, 2016), with 421 points. Besides, the science scores of Thailand students did not rise in following years in comparison with previous years. Another prominent finding also shown that one-fifth of students demonstrated higher knowledge of science than a given basic level. When considering separate areas in Thailand, students from all areas also had an average score lower than the OECD average. Following this, in the Northeastern area, the science average score was 418, which was lower than the Thai average (OECD, 2019), especially the provinces in the Mekong River Basin (MRB). The reason has derived from the limitation of cooperation in developing education at different levels. Therefore, it is important to change and keep up with the changes of the globalization and boost the educational cooperation between provinces in the Mekong River Basin.

Accordingly, Akarawang et al. (2015) revealed that in the past, Thailand teachers at junior high schools focused on the traditional teaching method by conveying their knowledge to learners. Nevertheless, with the changes of national policy, teachers have been encouraged to improve learning ways to students rather than knowledge transfer

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(Asanok and Chookhampaeng, 2016). Thus, media has been applied to encourage learners at educational institutions. On the other hand, most of teachers centered on developing and innovating teaching methods instead of learning innovation that stimulate students' self-learning skills and boost searching information from teacher-prepared media.

The research findings from OECD (2019) figured out that approximately 56% Thai students has science competence at Level 2. With this level, students could explain familiar and basic scientific phenomena and indicate correctly conclusions in congruent with available data; however, it can be seen that Thai students still have lower scientific ability than the average of other countries (OECD, 2019). Naluan et al. (2013) mentioned the main reasons pertain to the lack of opportunities to develop higher thinking, and limitation of learning content. Besides, the teaching and learning of the science subjects emphasized on memorizing rather than exploring knowledge, and the constraint of experimental practice.

Some research has pointed out that learning innovation has been developed to promote higher order thinking skills (e.g., critical thinking, problem solving, creative thinking and critical thinking) by applying theoretical principles into practice and combining with media features. There are the learning environments, skill sets, multimedia, online lessons and mobile learning (Hong et al., 2000; Hwang et al., 2018; Ku and Ho, 2010; Lee et al., 2004, 2021; Pedaste and Sarapuu, 2006; Perschbach, 2006; Prahani et al., 2020; Saido et al., 2018; Strycker, 2020; Torres and Cano, 1995; Uribe et al., 2003; Wang et al., 2009; Whittington, 2000). However, there is no educational institution promoting knowledge formation and higher order thinking skills based on the social and culture context, and the integration of local wisdom into courses to enable learners to learn and connect, then contribute to the sustainable creation of new knowledge. In addition, teachers had the misunderstandings of learning management or the development of learning innovation fostering higher order thinking skills (Kwangmuang and Chaijaroen, 2016).

In the design and development of learning innovation, it is important to focus on supporting learners' knowledge construction process and reflection instead of conveying and memorizing principles and facts (Chaijaroen, 2014; Jonassen, 2000; White et al., 1999). It can be seen that studying the understanding of cognitive processes is a new aspect enabling learning innovation to develop and enhance the learning quality. Hence, it might be interesting to further prepare necessary conditions to develop the quality of people and toward a wisdom and learning society in Thailand by increasing knowledge and basic skills, such as, analyzing, creating, solving problems, critical thinking, and team-working; having ethics, and working discipline to support and learn complex technologies easily, and to adapt to modern technologies and develop life-long learning skills.

Therefore, the aims of this research focus on:

(1) Designing and developing learning innovation in order to enhance higher order thinking skills for learners at junior high schools in Thailand;
(2) Measuring and evaluating the learners' higher order thinking skills;
(3) Exploring the learners' opinions on learning innovation to promote higher order thinking skills.

This study is quite promising in enhancing the intellectual potential of the learners, and improving the teachers' competency about learning management design, learning innovation development and higher order thinking skills for students. Besides, this paper is useful for policymakers and educators to design appropriate curricula and the learners' competence framework. The results of this study can also be used as a basis for research in education and social sciences.

2. Research questions

This study answers three following research questions:

(1) What components of learning innovation are designed to enhance higher order thinking skills for students at Thailand secondary schools?
(2) How are the students' higher-order thinking skills after experiencing learning innovation?
(3) What are the learners' opinions on learning innovation to promote higher order thinking skills?

3. Literature review

3.1. Learning innovation

Educators gave the definition of leaning innovation is the interplay between the complex set of practices, methods, and designs that are part of the attempts by higher education to improve teaching and student learning (Kim and Maloney, 2020). Moreover, a set of core educational values and principles to inform decision-making of teachers, who appropriate these principles, make reflective interpretation and discretionary judgment, and develop specific designs and actions to achieve desired outcomes (Zhang et al., 2008). The goal of learning innovation is not only to enhance learning outcomes, but also to improve the teaching experience as an opportunity of the development of transversal skills. The "Pedagogy-Space-Technology" Framework (Radcliffe, 2009) is the tool used as a starting point for the design of innovative teaching-learning experiences.

Foxon and Pearson (2008) emphasized that designing learning innovation aims to support those who do not have a specific pedagogical background and wish to appropriate the basic tools of good teaching design and then continue exploring the frontiers of innovation. It is considered as a set of logical and methodological tools to innovate teaching, finding approaches more in harmony with one's vision of the teaching-learning experience. From this principle it was found that researchers have developed various forms of learning innovations, such as the development of learning innovation as a game for enhancing the active of the undergraduate student (Areekul, 2020), creating and developing learning innovations using multimedia integrated with online social networks (Phudthonamochai, 2021); technology-supported learning innovation in cultural contexts (Zhang, 2010); institutional change and leadership associated with blended learning innovation (Garrison and Vaughan, 2013); e-learning innovation through the implementation of an Internet supported learning environment (Smith and Hardaker, 2000).

It can be seen that researchers have developed learning innovations that focus on the learners' thinking process, not only by transferring knowledge. Most of the innovations are on different platforms, but there has been no development of learning innovations that foster higher order thinking skills, especially in Thailand. Therefore, to develop people to be able to create knowledge and learn by themselves, learning innovation is important. This will enable learners to learn and develop students' potential in a sustainable manner.

3.2. Higher order thinking skills (HOTS)

It is interesting to show that students should be experienced learning which helps them enhance knowledge and thinking skills. Previous studies mentioned HOTS is considered as the ability of analysis, synthesis, evaluation, develop skills, estimate, generalize, and create thinking, make decision, set up objectives, critical and systemic thinking (Dillon and Scott, 2002; Miri et al., 2007; Zohar and Dori, 2003).

Some previous studies indicated that HOTS include two components, such as critical and creative thinking skills (Heong et al., 2011; Plan, 2014; Sulaiman et al., 2017); logical thinking, critical thinking and reasoning skills (Marshall and Horton, 2011). Ramirez and Ganaden (2008) focused on the three cognitive processes, namely analysis, evaluation, and creation reviewed as HOTS. Meanwhile, others mentioned

four aspects of HOTS, namely critical thinking, creative thinking, problem solving, decision making thinking (Apino and Retnawati, 2017; Lewis and Smith, 1993). According to Ahmad et al. (2017), HOTS is an important element in education because of its benefits in improving of students' learning performance, reducing weakness, interpreting, synthesizing, solving problems, and controlling information, ideas and day-to-day activities.

Zohar and Dori (2003) emphasized the development of HOTS is one of important objectives of educational institutions because of the its influences of learning performance. The findings from the study of Zohar and Dori (2003) noted that students with high learning outcomes achieved higher thinking scores in comparison with peers who have lower learning performance. Miri et al. (2007) suggested that teachers should develop professional programs to support and encourage students in accomplishing their tasks which is required by higher order thinking skills (Zohar and Dori, 2003). In addition, Sulaiman et al. (2017) concluded that teacher's knowledge and competence play critical roles in ensuring the effectiveness of the deployment of HOTS to enhance learning outcomes for students (Retnawati et al., 2018). Therefore, the development of learning models, teachers' knowledge and skills, and learning resources is necessary conditions to boost HOTS for learners (Retnawati et al., 2018).

3.3. Science literacy

Science literacy is considered as an important factor influencing learning achievement of the students. According to Rustaman (2003 as cited in Ardianto &Rubini, 2016), science literacy is conceptualized as the learner's capability in using science knowledge in order to identify questions, issues, to understand and make decisions, and draw conclusions relied on evidence. Similarly, Rusilowati et al. (2017) also mentioned science literacy is characterized by individual's ability to understand, communicate and apply science knowledge to solve problems of daily life based on science considerations (Jufrida et al., 2019). In the study of Rusilowati et al. (2017), it is found that the concern of school's principal, the implementation process of science teaching and the interest in science of students are three main factors having influence the science literacy attitudes.

According to Ardianto and Rubini (2016), the integration of using socio-scientific issues into learning content is useful to develop the scientific literacy of students. Besides, "guided discovery and problem-based learning models" are also used to improve critical thinking skills and learning achievement in science literacy. As a result, these models yielded satisfaction for students in enhancing their scientific literacy within two aspects including science content and

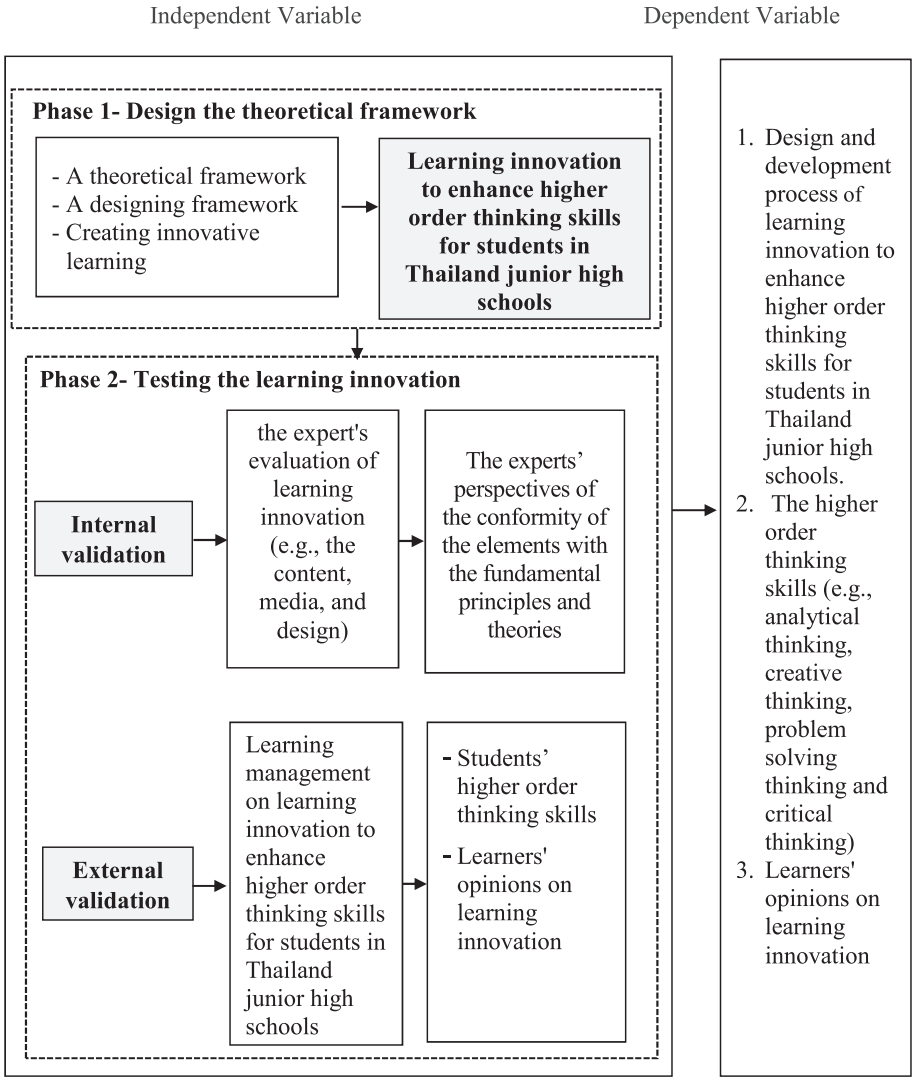

Figure 1. The conceptual framework.

competency. However, the results in the study of Nurlaely et al. (2017) revealed that the science literacy score of students is relatively low, thus, it is important to build a learning innovation model to improve science knowledge and skills of learners (Jufrida et al., 2019). Besides, Wang (2013) suggested that teachers should integrate and link science knowledge with daily life to improve the students' understanding of multiculture.

3.4. The conceptual framework

The researchers studied relevant documents and literature of cognitive processes to serve as the basis for designing learning innovation to enhance higher order thinking skills. The model research is used in this study focusing on the process of developing a model designed by Richey and Klein (2007). This model is in accordance with the development of teaching technology or educational technology and teaching design to develop teaching and learning models. This research used mixed-research method to measure and evaluate the learning innovation in two phases and was expressed in the following conceptual framework (Figure 1).

We studied relevant literature and formed a theoretical framework as shown in Figure 2. As a result, constructivist is in line with learning management in the educational reform and learning era which learner is the creator of self-knowledge and cognitive processes. It serves as the basis for designing innovative learning models promoting advanced thinking. Fundamentals of pedagogy include constructivist models, namely, the constructivist learning environments (CLEs) Model (Jonassen, 2000), SOI (Select, Organize, and Integrate) Model (Winarsih, 2018), open learning environments (OLEs) (Hannafin, 1999), and Cognitive Apprenticeship (Garner, 2012), information processing theory (Klausmeier, 1992). Media theory, media symbolic systems, and learning multimedia are also studied. Besides, thinking skills are as a basis for designing innovative learning, such as, 1) Analytical thinking (Jarutkamolpong et al., 2018) consisting of five phases; 2) Creative thinking applied from Guilford (1967); 3) Problem solving applied from Jonassen (2000); and 4) Critical thinking (Sangboonraung et al., 2019), as well as finding the effectiveness of learning innovation.

Next, based on the conceptual framework and theoretical framework, a designing framework of learning innovation to foster advanced thinking for learners, and convert theoretical principles into practice was drafted. This framework includes four important components: 1) Stimulating the creation of cognitive structures and promoting higher-order thinking skill, 2) supporting to cognitive balance, 3) promoting the expansion of cognitive structures and higher-order thinking skill, 4) helping cognitive balance (Figure 3).

4. Methodology

This research is divided into two phases: Phase 1, Design the theoretical framework; Phase 2, Testing the integrity of learning innovation.

4.1. Phase 1. Design the theoretical framework

In this phase, researchers carried out following steps:

(1) Study and analyze principles, theories, and research on the design of learning innovation (i.e., constructivist learning theory, higher order thinking skill, media symbol system, network technology teaching and learning context).
(2) Synthesize the theoretical framework from the analysis of related documents and research;
(3) A designing framework of learning innovation is drafted to enhance higher order thinking skills in schools and proposed to the research team to criticize.

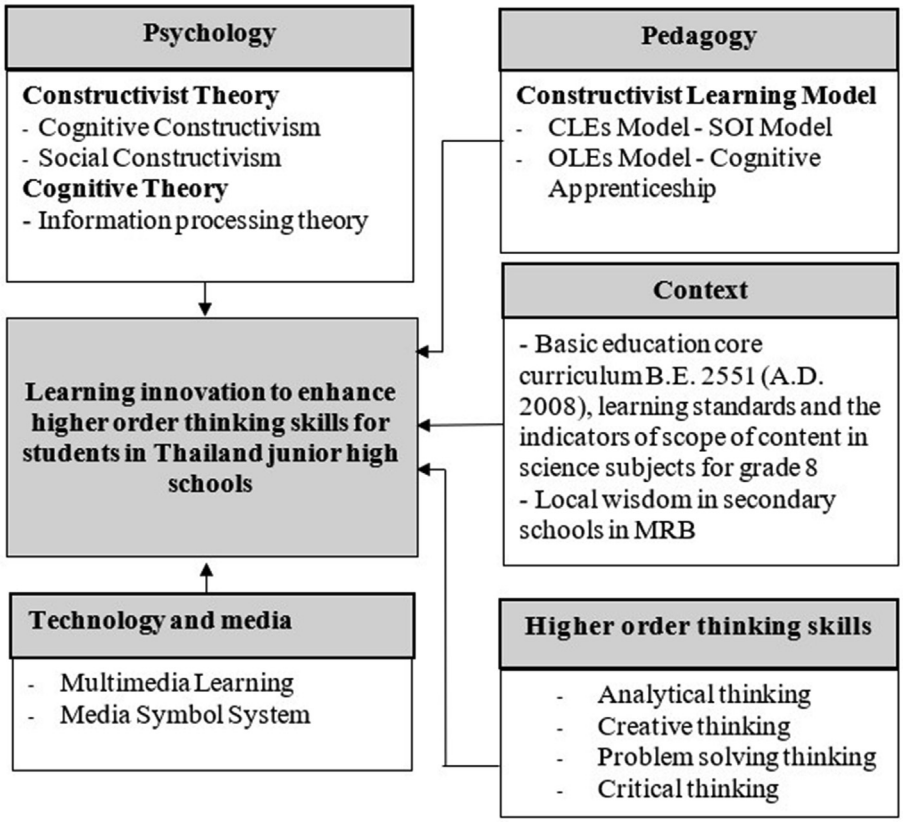

Figure 2. A theoretical framework.

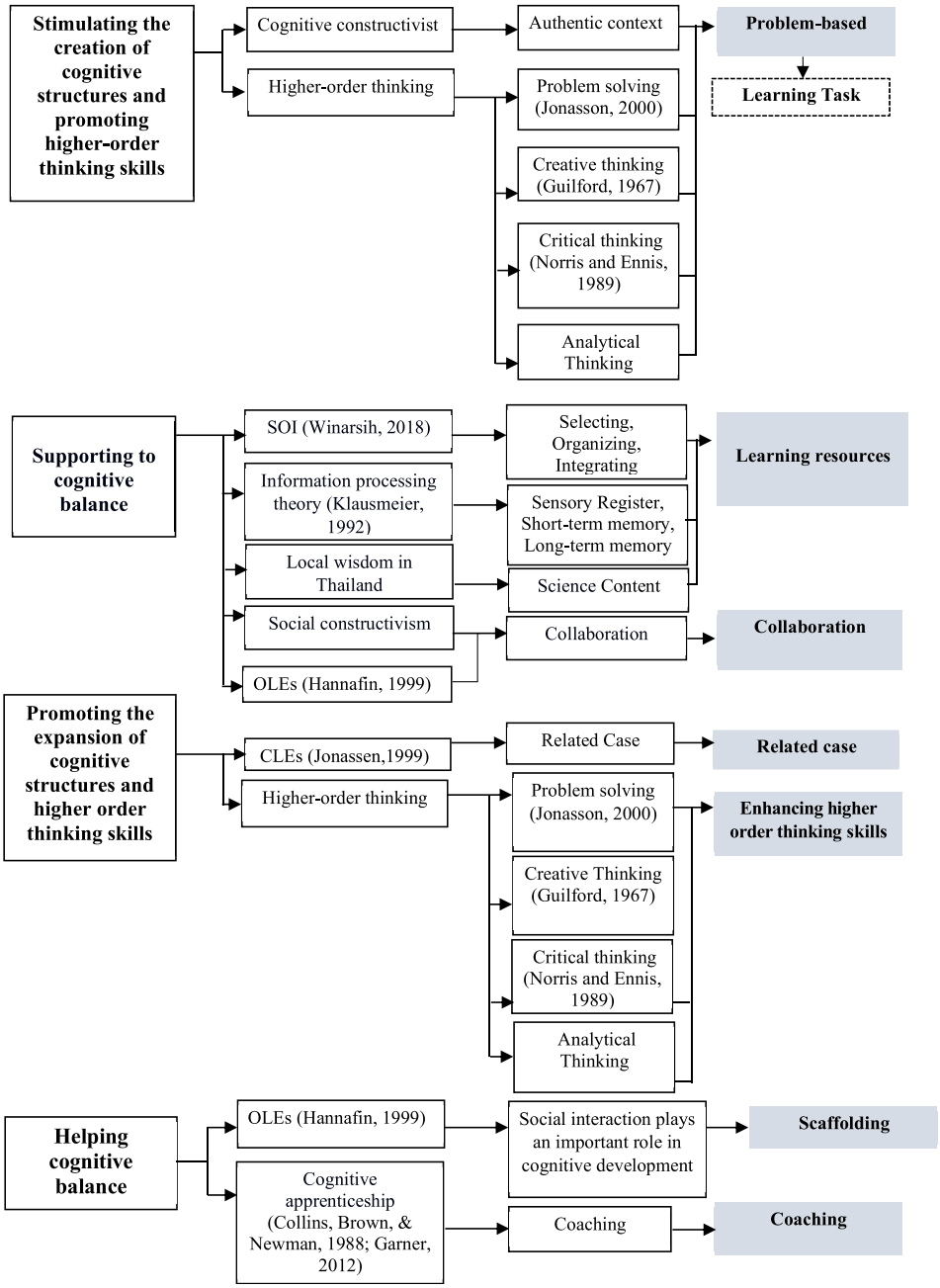

Figure 3. The designing framework of learning innovation.

4.2. Phase 2. Testing the integrity of learning innovation

4.2.1. Participants

The participants of this study consist of:

- 13 experts are lecturers at Thailand universities to validate the quality of preliminary learning innovation concerning content, design and media;
- 10 teachers and 30 students in a sample group at five secondary schools to explore the school's context and have deeply understanding of real situation of learning innovation;
- Three experts from universities who have experience about learning innovation to validate the quality of the elements of learning innovation after revising based on the suggestions of 13 abovementioned experts' suggestions;
- 153 grade 8 students in five junior high schools in five provinces of Mekong River Basin, Thailand (namely, Mukdahan, Nakhon Phanom, Sakon Nakhon, Nong Khai, and Bueng Kan Province). The choice of students in the Grade 8 level is to clarify the integration of local context and wisdom into science content which mainly concentrated in subjects in grade 8.

4.2.2. Research instruments

There are some research instruments used to monitor the quality of learning innovation and higher order thinking as follows:

- An evaluative form is used to examine the quality of learning innovation, consisting of open-ended questions with reasons or suggestions to improve issues with consistent or inconsistent opinions;
- An interview protocol is done to explore the teachers' perspectives of learning innovation and students' higher order thinking skills;
- A questionnaire with yes/no questions and recommendations is used to survey the learners' perspectives about learning innovation;

- A pre-test and post-test are used to measure academic achievement of Grade 8 students who experienced the learning innovation;
- An interview protocol for learners (unstructured interviews and semi-structured interviews) on the application process of learning innovation, and study pre- and post-learning learners' solutions on the learning innovation to enhance higher order thinking skills;
- The evaluation form is sent to experts to get their opinions on the use of learning innovation;
- Measurement tools to evaluate of the learners' creative thinking, analytical thinking, critical thinking and problem-solving thinking;
- A questionnaire is used to explore the learners' perspectives after experiencing the learning innovation.

4.2.3. Data analysis

Researchers used various data analysis ways for collected data, including:

- In term of qualitative data from interviews and evaluation form, the data interpretation, synthesis and summary techniques are applied to examine the quality based on experts' perspectives, and get learners' opinions on learning innovation situation.
- Regarding the quantitative data, SPSS software is done to process data from questionnaire with the descriptive statistics (e.g., percentage (%), mean (X), and standard deviation (S.D.))

Measuring higher order thinking skills of learners is used by specific instruments based on previous studies. These would be mentioned in 5.2 The learners' higher order thinking skills.

5. Results and discussion

5.1. The results of the design and development of learning innovation to enhance higher order thinking skills for students

5.1.1. Phase 1 - Design and development of learning innovation

The real situation of learning innovation is not detailed mentioned in this paper. However, the results of teaching and learning in science subjects at secondary schools found that the teachers' teaching has not promoted the learners' problem solving. Most of the teaching styles have focused on lectures because they fear that the students would not understand the content. Students have just waited for receiving knowledge from teachers. Consequently, they could not distinguish different things because they lacked analytical thinking, critical thinking, creative thinking and problem-solving thinking skill. Furthermore, teachers have not had hands-on examples to encourage students to link knowledge and apply in daily life. Therefore, it is crucial to design and develop learning innovation to enhance higher order thinking skills and combine with the integration of local wisdom.

The details of the design and development of learning innovation are mentioned in six components:

5.1.1.1. Problem-based. Based on the Piaget's theory of cognitive development (1963), this concept emphasized that the learner is as the creator of knowledge by taking actions. If the learners are motivated by a problem creating an intellectual conflict (Cognitive conflict) or loss of disequilibrium, they must try to adjust the cognitive structure into equilibrium. Therefore, the research team has converted this theory into practice by designing a problem situation. Following this, an authentic context is presented in the form of a problem regarding the real context of the story to help learners refer or relate to their previous experiences. Besides, a case study concerning local wisdom in the MRB is integrated and combined with the design of a learning mission promoting advanced thinking (including, problem solving, creative thinking, critical thinking, and analytical thinking) (Figure 4).

5.1.1.2. Learning resources. The learning resources are designed by integrating subject content according to the core curriculum for the grade 8 students, the science subjects and local wisdom in the Mekong River Basin combine with the principles of learning theory based on information processing theory. Then, we designed information for knowledge sources by presenting information with a mind map showing relationships of all contents; using animated graphics to show changes in objects and to highlight important information, such as, color, size; underlining designing information as a conceptual model, a visual concept of the connection; and classification of information by grouping related information together in a hierarchical network to show the learning resources for each innovation. As a result, (1) Fish farming in cages is the ecological content (biology course) is designed to enhance analytical thinking skill. (2) A device for fishing in the Mekong River relied on the liquid solid properties (Chemistry course) and fluid (Physics course) is integrated to improve creative thinking skill. (3) The fermented fish in the context of chemical reactions in living cells and the digestion of microorganisms and protozoa (Biology course) is used to improve problem-solving skill. And (4) Food processing and preservation in the context of energy and heat and chemicals used in daily life (chemistry course) is designed to enhance critical thinking skill.

5.1.1.3. Scaffolding. It is used for cognitive balance promoting advanced thinking. According to Vygotsky's theory (1978), "Social interaction plays an important role in cognitive development". Ideas of the cognitive development potential may be limited to the phase of development known as the zone of proximal development if the student is below the zone. It is essential to support to learning known as Scaffolding, combined with the foundations of open learning environments (OLEs) of Hannafin (1999) and divided into four bases: 1) conceptual scaffolding,

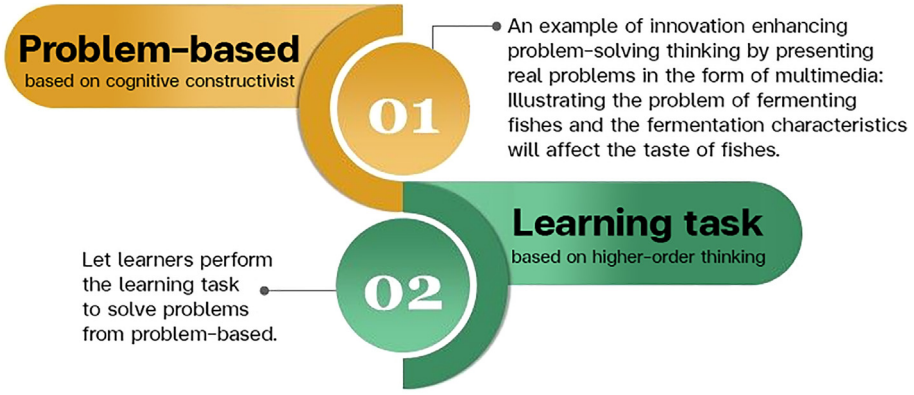

Figure 4. An example of problem-based learning.

2) metacognitive scaffolding, 3) procedural scaffolding, and 4) strategic scaffolding.

5.1.1.4. Related case. Based on the design of a constructivist learning environment of Jonassen (2000) known as CLEs (Constructivist learning environments), we designed a case study relating to a similar case to encourage learners to apply their knowledge to solve problems. For close cases, it allows students to learn from nearby cases to solve new problems that they are facing.

5.1.1.5. Coaching. The researchers draw on the principles of the cognitive apprenticeship model (Collins et al., 1988; Garner, 2012), a constructivist approach to learning management to change the teacher's role in transferring of knowledge, and guiding learners to learn, think and build their own wisdom. In addition, the principles of Intellectual Practice (Apprenticeship) of Collins et al. (1988) are designed to help new learners become an expert and intellectual internship when working. A classroom coaching and online coaching are designed to develop problem solving expertise. The coach also observes learners when they try to complete their mission and provides hints and assistance when needed. Learners could ask an expert anytime they want. Besides, the principles of Herrington and Oliver (1997) on how to design an appropriate situated learning is used to stimulate the learners' thoughts and to solve learning missions.

5.1.1.6. Higher order thinking skills. The theoretical principles promoting higher order thinking skills are used as the basis for the design to enhance:

1) *Problem solving thinking* - The simple problem-solving process of Jonassen (2000) is applied to help learners face with problems in real contexts and practice problem solving skill by problems with simple structures, then assign missions for students to solve problems according to the process (Figure 5).
2) *Analytical thinking* - In order to promote analytical thinking and help learners deal with situations and problems in real contexts and practice critical thinking, a learning mission promoting analytical thinking (Figure 6) is carried out the following steps (Jarutkamolpong et al., 2018): (1) Extent specify, (2) Consideration, consisting of identification, categorization, expiation, prediction, and discrimination, (3) Correlation, (4) Conclusion, and (5) Utilization.
3) *Creative thinking* - It is a process encouraging students' creative thinking based on Guilford (1967) model. Four aspects of thinking are designed: 1) Fluency thinking - help students find answers as quickly as possible in the limited time of 1 min; 2) Flexibility - allow students to create ideas to change the interesting presentation form of different brochures; 3) Originality means the ability to create ideas - requires students to design a presentation of their local story by using the appropriate devices or technologies; and 4) Elaboration - develop thinking ability to expand, add or create new ideas from evaluating the answers according to the specified criteria (Figure 7).

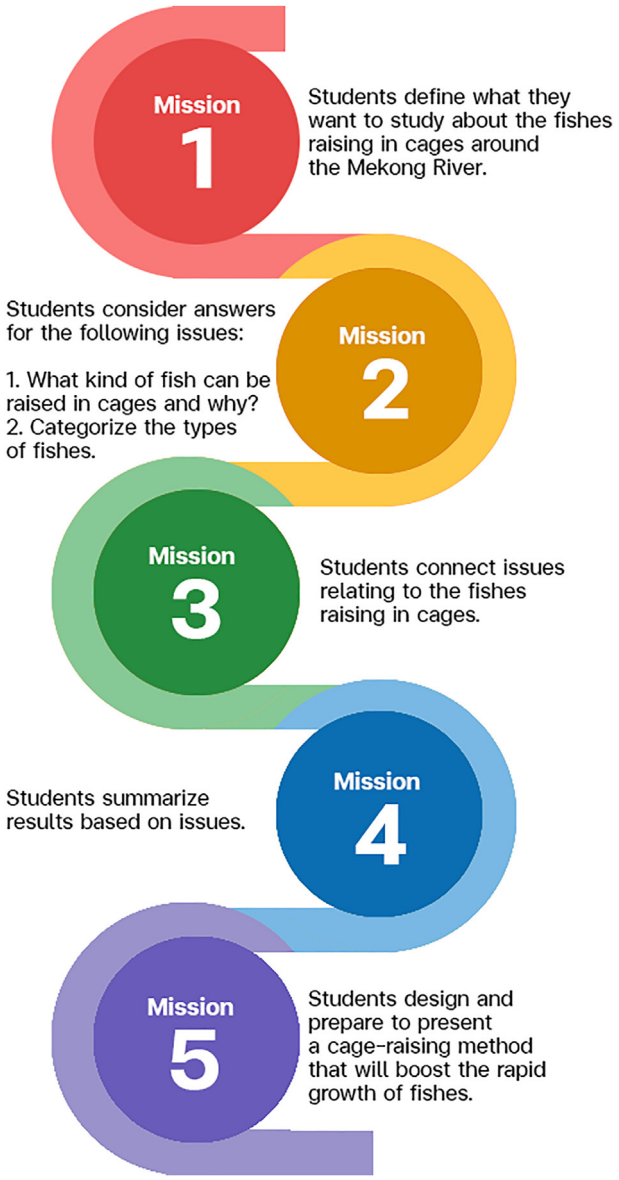

Figure 6. Learning missions promoting analytical thinking.

4) *Critical thinking* - Relied on critical thinking principles (applied from Norris and Ennis, 1989), six learning missions are carried out as follows: (1) Deductive summary by allowing students to give examples and then teach theories; (2) Provide meaning by allowing learners to identify similarities and classify; (3) Considering the reliability of the data source; (4) Inductive summarization by giving students an

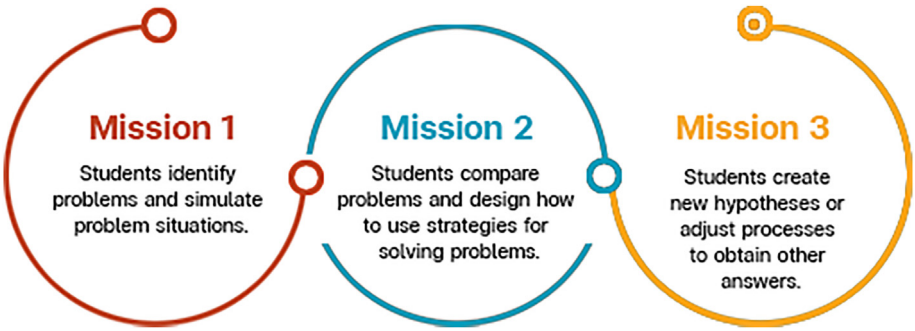

Figure 5. Learning missions to promote problem solving thinking.

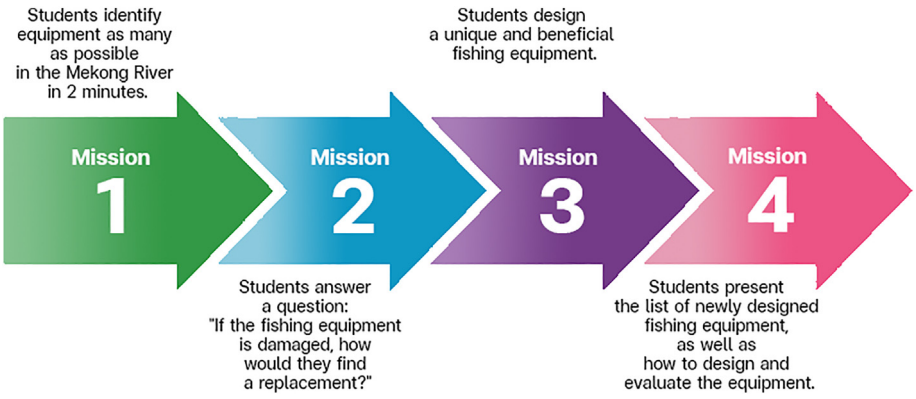

Figure 7. An example of the encouragement of creative thinking.

overview example of the ability to reason, as well as to draw conclusions by giving comprehensive examples; (5) Summarizing tests, hypotheses and predictions: students could consider reasonable alternatives based on available information and evidence; (6) Defining and specifying assumptions by giving learners the ability to reason to formulate problems (Figure 8).

In term of the evaluation of the effectiveness of learning innovation. Examining the effectiveness of learning innovation is done to determine the quality of the model from the reviews of 13 experts. An evaluation form with open-ended questions pertaining to the design, content and media of learning innovation used in teaching and learning is sent experts to get their perspectives. The findings are found that all aspects are appropriate and consistent, and help promote knowledge creation and enhance higher order thinking skills for students.

5.1.2. Phase 2. Testing the integrity of learning innovation

The objective of this phase is to examine the various components of the model by using experts' perspectives and external validation, the impact of implementing innovative learning techniques, including advanced thinking of learners, academic achievement and learners' opinions of innovative learning.

5.1.2.1. Internal validation. The learning innovation is examined by three experts through an evaluation form with relevant questions to evaluate teaching design, the quality of design and media. The results are found that the overall design and development of the learning innovation is theoretically consistent and used as the basis for designing a conceptual framework of learning innovation.

5.1.2.2. External validation. The learning innovation is applied with target learners in real context to evaluate its influence. As a result, the advanced thinking skills of the learners are higher than before learning, with a post-test average score ($X = 15.86$, S.D. $= 1.41$), and 83% students passed 70% criteria as specified by the educational institutions. An instrument used to evaluate learning innovation of students consists of the measurement of the learners' creative, analytical, critical and problem-solving thinking based on the test. This test is designed based on the content of the science courses to develop an ecosystem, the properties of solids, liquids (chemistry), and fluids (physics), reactions, microbial and protozoa digestion, energy and heat, and daily chemicals. Besides, learners said that learning innovation (content, multimedia, and design) helps promote their learning, knowledge creation, and advanced thinking. In addition, the results of learning innovation to enhance higher order thinking skills for students in Thailand junior high schools

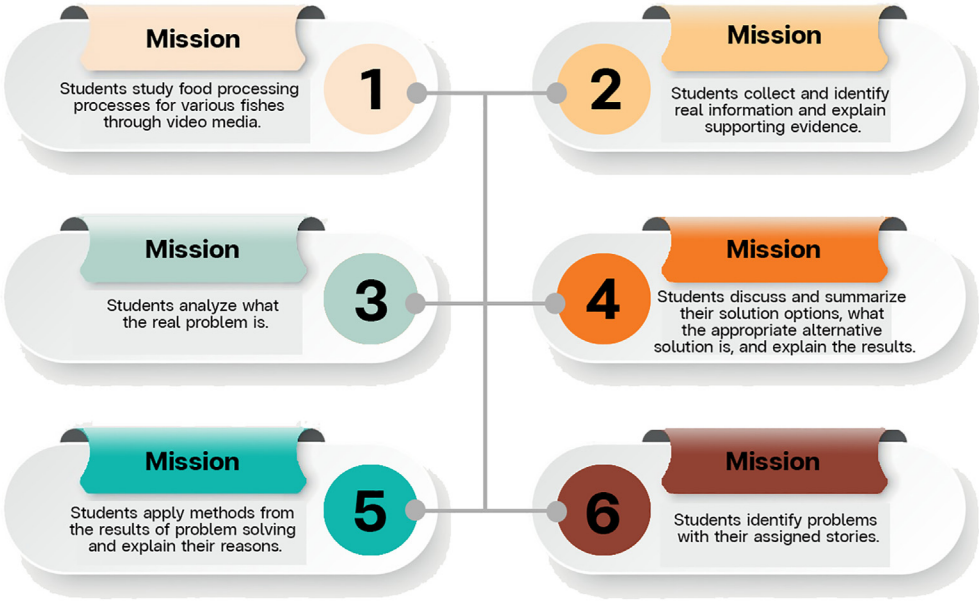

Figure 8. An example of six learning missions of critical thinking.

are found that all components are very effective in promoting learners' advanced thinking. Following this, the design and development of learning innovation help enhance advanced thinking (i.e., problem solving, analytical thinking, creative thinking, and critical thinking), stimulate students' curiosity and information seeking to answer questions or learning tasks, and create new ideas.

These results seem to support the evaluation of previous studies, which confirmed that design and develop a learning environment by applying the key elements and principles of constructivist theory to design and coordinate with the media in different ways could facilitate students' learning, promote self-knowledge creation, stimulate learning interest, and promote team-working (Hadjipanayi and Michael-Grigoriou, 2020; Pedaste and Sarapuu, 2006; Shah, 2019; Xu and Shi, 2018).

5.2. The learners' higher order thinking skills

The measurement of higher order thinking skills of students from the survey and in-depth interviews is shown in Table 1, and explain detailed as follows:

5.2.1. Problem-solving thinking

The results of in-depth interviews of problem-solving thinking are shown through three steps applied by Jonassen (2000), (1) Problem representation is found that students must connect problems with their daily life, identify the problems and what available solutions to solve them based on previous experiences. (2) Searching for solutions - students must associate problems with solutions, analyze the goals, solve problems, and use methods to separate the problem into subsections to understand reasons, and a simple solution test is created. (3) Implement solutions - the learners simulate the situation and experiment assumptions they have planned to solve the problem and to find the best solutions. The results of the evaluation by using the scale of Jonassen (2000) are figured out that the problem-solving thinking of learners after learning innovation has higher creativity with overall score ($X = 11.01$, S.D. $= 2.25$) in comparison with before score ($X = 3.05$, S.D. $= 1.52$).

The results of this study based on ID Theory could bring problem-solving principles into practice in each component of learning innovation. For example, the mission design for students to analyze problems according to the problem-solving processes of Jonassen (2000) is carried out through three steps. It is a computer-based design allowing students to think and solve problems with their peers in a three-step process (e.g., problem representation, search for solutions, implement solutions) by using the features of multimedia. This also allows students to interact and record what they think in the problem-solving process into the learning innovation immediately. The previous results highlighted that promote problem-solving thinking in the classroom helps learners get the higher learning achievement (Hew and Knapczyk, 2007; Hernandez-Serrano and Jonassen, 2003; Hong et al., 2000; Mooney et al., 1999; Pedaste and Sarapuu, 2006; Uribe et al., 2003; Wang et al., 2017; Wattanachai et al., 2010).

5.2.2. Analytical thinking

The learners' analytical thinking is expressed through five steps relied on the study of Jarutkamolpong et al. (2018):

- *Step 1.* Extent specify - learners are able to define information by considering what they are learning, including the collection of relevant content and knowledge.
- *Step 2.* Consideration is divided into six parts: 1) Additional Query - the problem set earlier and effort in setting up new problems to find answers in multiple dimensions are considered carefully. 2) Identification is found that learners able to distinguish different subsections, including the detailed information gathered. 3) Categorization - A group of similar things following the characteristics or qualifications, including using previous knowledge or experience for classifying, distinguishing characteristics of each category could be effectively categorized by students. 4) Expedition - Learners could generate additional ideas by describing things considered, classified or categorized; and extend the connection with forward-anticipated information. 5) Prediction shows that learners could reasonably predict probabilities, judge the facts from personal experience, know the core cause to solve problems, assess the situation and make decisions. 6) Discrimination - students are able to compare events or things to see the similarity or different characteristics of each category (e.g., consistency, conflict, positive effect, negative effect, cause, effect, sequence, and continuity) to provide a clear summary of the characteristics and find the connection points for further data analysis.
- *Step 3.* Correlation. It is found that the students could relate various information, then rationalize what happened to find the truth and a logical relationship.
- *Step 4.* Conclusion - Comments could be concluded by summarizing and giving the meaning of data; capture points and have conclusions from those clearly defined.
- *Step 5.* Utilization - Learners could create results for tangible benefits, gain experience from problems or events.

The result of the evaluation of the analytical thinking after joining in the learning innovation from 153 students with a full score of 60 points is higher than before learning with the overall average score $X = 47.35$, S.D. $= 5.96$ compare to $X = 21.98$, S.D. $= 5.43$. Therefore, schools could use analytical thinking to help learners study and gather information, consider problems, classify, categorize, expand forecasts, connect, find relationships, draw conclusions and apply at every step. It is interesting that other research also supported to the findings of this study relating to apply analytical thinking as the basis for the design of learning management, encourage and enhance learners' learning innovation (Irwanto et al., 2017; Rery and Erna, 2020; Rengganis and Yulianto, 2018; Rosadi et al., 2018).

5.2.3. Creative thinking

The creative thinking measurement based on the study of Guilford (1967) includes four dimensions:

1) *Fluency* is the ability to generate ideas for answers or find a variety of solutions to problems fluently, fast, large quantity in limited time with two aspects, (1) Word fluency - students could answer a lot of questions in a limited time by trying to relate to their daily life, (2) Associative fluency - the learners try to connect and compare to find the correlation of the similarity things as many as possible.
2) *Flexibility* - Different ideas to achieve the same goal could be created by learners; for example, using different fishing equipment to replace

Table 1. The result of students' higher order thinking skills.

Higher order thinking skills	Before learning	After learning
Problem-solving thinking *(full score: 15)*	$\bar{X} = 3.05$; S.D. $= 1.52$	$\bar{X} = 11.01$; S.D. $= 2.25$
Analytical thinking *(full score: 60)*	$\bar{X} = 21.98$; S.D. $= 5.43$	$\bar{X} = 47.35$; S.D. $= 5.96$
Creative thinking *(full score: 40)*	$\bar{X} = 10.77$; S.D. $= 2.17$	$\bar{X} = 31.81$; S.D. $= 3.27$
Critical thinking *(full score: 30)*	$\bar{X} = 11.16$; S.D. $= 2.10$	$\bar{X} = 27.63$; S.D. $= 2.28$

the existing one and designing them with appropriate size and quantity.

3) *Originality* - students have designed fishing equipment based on the principles of scientific calculation.
4) *Elaboration.* It is found that the students could add the concept of device design to replace what is lacking.

The assessment result of the creative thinking in innovative learning is figured out that after class students get the higher overall score (X = 31.81, S.D. = 3.27) than before learning with X = 10.77, S.D. = 2.17. This study differs from previous research that learning innovation relied on the framework of Guilford (1967) is designed and developed in all four areas. This is a concrete basis for fluency thinking, flexible thinking, initiative, and careful thinking and become the basis for design and learning innovation fostering advanced thinking in schools of MRB, Thailand.

These results seem to support the evaluation of the research of Buzan (2005), Ma and Corter (2019), and Tang (2017), who confirmed that educational institutions need to organize the teaching and learning activity by designing and developing a learning innovation to promote the students' creativity and research in four dimensions (e.g., fluency, flexibility, originality, and elaboration).

5.2.4. Critical thinking

The basis of Norris and Ennis (1989) is used to measure critical thinking skill based on six steps through in-depth interviews. The results indicated that in every step the students could:

- *Step 1. Deductive summary* - illustrate the teaching approach and overview of theory.
- *Step 2. The meaning* - collect data, classify and select the actual data and explain the supporting evidence. When a student faces to a problem situation, he/she can give meaning to what happened in that situation. Besides, they could define the vocabulary clearly, face to the situation and problem in the story.
- *Step 3. Consider the credibility of the data source* - understand problems and take reliable and appropriate sources of the context, compare the true data, and explain the obtaining process.
- *Step 4. Inductive summary* - discuss and summarize options for solving problem.
- *Step 5. Conclusion by testing, hypothesis and prediction* - know how to apply each method to solve the problem and explain the reasons.
- *Step 6. Defining and specifying assumptions* - identify problems with the given story. When facing with problem situations, students could identify problems and what happened, and able to think of possible answers to that question.

The evaluation of learners' critical thinking by applying the Cornell critical thinking level X pointed out the overall higher score (X = 27.63, S.D. = 2.28) than before learning (X = 11.16, S.D. = 2.10).

The learning innovation has been designed to promote critical thinking and to give opportunities for students to practice thinking and to carry out their solutions. It requires a critical thinking process to apply the design of learning management that is suitable for the context of the learners. This is in line with the research of Miri et al. (2007), Cano and Martinez (1991), Ku and Ho (2010), Lee et al. (2004), Perschbach (2006), Kuhn (1999), Wang et al. (2009), Torres and Cano (1995), and Whittington (2000). Critical thinking could highly foster and develop by using learning materials, such as, skill training, learning on the network, organizing activities or a learning environment promoting critical thinking following the findings in the study of Hurt et al. (2003). In addition, collaborative learning techniques to solve problems are also a method encouraging learners to develop critical thinking.

5.3. The students' opinions of learning innovation to enhance higher order thinking skills

The learners' opinions of the elements of learning innovation show that the content has the highest value (X = 4.61, S.D. = 0.61), followed by design (X = 4.28, S.D. = 0.69), and multimedia (X = 4.02, S.D. = 0.95). The findings of a detailed analysis of the perspectives are as follows:

5.3.1. The content is interesting and in congruent with the level of the students, and the learning of science subjects

- The content is up-to-date, completed and comprehensive, clear and conducive to study, research and get knowledge, and create easily hierarchical content. Besides, the design of content helps develop learner's knowledge and thinking;
- The language is used compact, hierarchical, easy to understand, and sufficient for learning or building knowledge, and can be used and linked with daily life;
- The format of content presentation is interesting and encourages the learners' interests by using letters, word emphasis, color, and animation;
- Content presentation helps process information easily and learn better;
- The illustrations are consistent and help promote good learning, including real and virtual pictures. However, some contents could not fully cover into all classroom lessons.

5.3.2. The multimedia

It is indicated that a navigation tool has designed to help find information more easily and meet the students' needs. Besides, a constant navigation design also allows easy access and search for information. There is an icon which can convey the meaning of various information sources. It is also linked to allow access to various information, conversations, and learning through Facebook.

In order to convenient access and easy to use, the design of the architecture elements is eye-catching and attractive. It is appropriate and consistent with the content, and boost the learning. Also, the animation helps learners pay attention and promote learning and information processing. The images and text sizes are used in accordance with the content by using appropriate, harmonious, and pay attention colors.

5.3.3. The design

The design is evaluated based on seven aspects as follows:

1) *Problem situations* are designed according to the theory of information processing by inserting the story into a problem situation, and using conversations causing discrepancies and closing to the real context by creating an animation. It allows learners to control their own learning, and is embedded into the situation, and a real context of the local wisdom; helps build knowledge and encourage learners to connect experiences used in real events, to analyze and ponder the issues they want to find answers. Problem situations also motivate students to think critically the issues that need to be resolved.
2) *The learning resources* have designed as a library of problems closing to the real context by creating an animation. This design allows students to search for information from various sources.
3) *Scaffolding* allows research or guide to perform missions.
4) *Collaboration* supports cooperative learning and working in groups, encourages everyone to participate in learning, to create and exchange ideas and solve problems together by finding possible

solutions from a variety of perspectives. It also supports the interaction between learners or experts through Facebook and expands ideas and encourages the learning.

5) *The higher order thinking skills* are designed to help enhance the thinking process, including problem solving, critical thinking, creative thinking, and critical thinking.
6) *Coach* - Learners are able to communicate and provide information to boost thinking and find answers, as well as to carry out their learning missions actively. Besides, there are the designs providing guidance, mentoring and giving advices to the learners.
7) *Related case* allows to see the example cases or how people have done it successfully to use as a guideline for solving different problems.

The findings are found that the design is consistent according to constructivism, and in line with the study results of Pande and Bharathi (2020), Jirasatjanukul and Jeerungsuwan (2018), Pedaste and Sarapuu (2006), and Yaisomboon and In-Udom (2011), who determined that the screen is beautiful, colorful, interesting and comfortable. The characters are appropriate, clear in terms of learning content and learning resources. Besides, it is easy to understand, interesting, adequate content to perform a learning mission. The content can be applied and helps enhance thinking, problem solving, and being up-to-date. This result also consolidates the perspective of Wattanachai et al. (2010) in term of the content of learning have sufficient information for solving problems and can be used in daily life. Furthermore, the media features are designed to help create the understanding and meaning of various sources of information, and search for information at any time by using easy-to-understand languages without translation.

6. Conclusions and recommendation

The findings of this study indicated that the design and development of learning innovation bring benefits for students in junior high schools at five provinces of MRB, Thailand. There are some prominent highlights summarized based on research objectives as follows:

(1) The components of learning innovation are properly designed and applied into learning to enhance the creation of knowledge and high order thinking skills of students at junior high schools;
(2) Students experienced learning innovation have higher average scores than before learning in four skills, namely, problem solving, analytical thinking, creative thinking and critical thinking.
(3) Concerning the students' opinions on learning innovation, they appreciate the content, multimedia and design of learning helping enhance higher order thinking. However, the results of this research cannot completely cover all lessons taught for students.

Thus, some recommendations are suggested for junior high schools, educators, and teachers relied on the highlighted findings:

(a) Educational policy makers should design and issue a general competency framework and national curriculum for junior high schools to promote the development of learning innovation for students;
(b) Educational institutions need to use common framework and standards to integrate and create the curriculum and syllabi enhancing the enhanced thinking;
(c) Teachers could design lessons and apply practical situation in daily life into lectures to stimulate and boost the higher order thinking skills for learners.

The findings of this study have both practical and theoretical implications:

- The results can be used as a basis for designing the learning arrangements enabling learners to use advanced cognitive and thinking skills to solve their problems, and guide the design and development of learning innovations in other contents to enhance higher order thinking skills for learners;
- Help educators, teachers and other stakeholders have the profounding understanding of the practical situation of learning innovation and higher order thinking skills of students, then issue holistic solutions to enhance this situation at junior high schools in Thailand.

This study only designs and develops learning innovation to enhance higher order thinking skills for students at five provinces in MRB, Thailand; therefore, the future research should focus on:

- Studying the social and educational environment, etc. regarding the higher order thinking skills of learners who integrate local wisdom culture in accordance with the Thailand context;
- The cognitive process of the learner, such as the cognitive load, scientific thinking, change of concept, and mental representation with learning innovation;
- The impact of learning innovation components in enhancing higher order thinking skill for students in Thailand junior high schools.

Declarations

Author contribution statement

Parama Kwangmuang: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Suwisa Jarutkamolpong, Watcharee Sangboonraung, Srisuda Daungtod: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data.

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The authors declare no conflict of interest.

Additional information

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