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Curriculum development for enhancing grade nine students' systems thinking

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The objectives of this research were to study the development of a curriculum for enhancing grade 9 students' cognitive skills using a curriculum based on Systems Thinking Process. There were 3 phases: 1) studying of the problem; 2) development of tentative curriculum; and 3) implementation of the curriculum in a pilot study. The samples were 32 students studying in Ban Phon Kroke School. The statistics used for data analysis included Percentage, Mean, Standard Deviation, Content Analysis and F-test. The research findings showed that the students were competent in using the Systems Thinking Process. Particularly, every student was able to determine the problem, specify variables relating to the problem, write a chart indicating behavioral pattern relating to the problem as well as causal cycle chart, present the thinking process outcomes, evaluate thinking process, and reflect the correct ways of thinking. The comparative findings of competency in using the Systems Thinking Process showed that the students had a higher posttest competency than the pretest at .01 level of significance. Additionally, the students said that the curriculum was highly appropriate. A longer period of follow up in the curriculum usage should be performed to see whether the students retain this competency and whether their behavior stil expresses this competency in Systems Thinking Process.

Key words: Curriculum development, knowledge management, systems thinking process

INTRODUCTION

The current world society is complex and related with each other intensively. It is not easy to solve various problems. We often solve the problems ignorantly without understanding the cause as well as relationship of problem clearly. This makes the new problems to continue. Since the world changes with time, the connection between problems is more complex. Consequently, both knowledge and learning are very much important to the future world. Furthermore, for us to live in this world creatively and comprehensively, the systems thinking would help us to know the connection between different phenomena in our lives. Systems thinking is a framework for understanding how people learn causes and effects. In Systems thinking, thinking is viewed holistically as a framework to understand patterns as well as their relationships. The special attribute is to view complex things in a way that they can be managed (Senge, 1993). The approach is promoted by Pegasus

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Communications (2000), which describe Systems Thinking as an approach which causes one to respond to a situation and the patterns relating to the new practice guideline in better ways. As a result, the thinking process is continuously improved. A systematic approach to thinking is likened to a special language in which the learner could create better communication with surrounding systems. The Systems Thinking approach is an effective instrument for viewing the situation as well as developing one's understanding of factors and behaviors that people could communicate with other people. Furthermore, it could help in designing a system for managing problem solving. Senge (2000) defined the Systems Thinking Process as a way to see any system through a method of four levels of thinking: the phenomenon or incidence level (events), the trend level and pattern, the structure level, and the mental model.

When a school tries to teach its students about thinking process, it has to change many things including curriculum, instruction, measurement, and classroom management. The curriculum should respond to the needs of the country, community, and locality, all of which are relevant to students' habit, characteristics, preferences, cultures, and merit without limiting learning to only the classroom. We could learn anytime and anywhere. When children are faced with problems, they should be able to use their logical as well as abstract thinking. They should set their hypothesis, try it out, control the variables, record the occurred outcomes, and conclude systematically. Educators commonly view grade nine students between ages 14 and 16 as in their transitional stage.

Their intellectual development includes the development of abstract thinking as well systematic thinking (Inhelder and Piaget, 1958). Consequently, they should be trained in the systems thinking process so that they would be able to view and solve the problem situation in all aspects. The curriculum development for grade nine students needs to come up with important techniques in developing the students to be able to use their systems thinking as effective guidelines for knowledge management to enhance their competency in using systems thinking.

Research objectives

1. To study the problem of knowledge management of grade nine teachers.
2. To develop a curriculum for enhancing grade nine students' System Thinking Process.
3. To study the implementation of the curriculum for enhancing grade nine students' Systems Thinking Process.

METHODOLOGY

Participants

The samples were 32 students studying in Ban Phon Kroke School, the Office of Surin Primary Educational Service Area Two, during the first semester of 2013 academic year. They were selected by purposive sampling.

Procedure

The research and development of this project consisted of three phases as follows:

Phase 1: the study of problem

1. Theories, documents, and related literature in curriculum development were studied (Taba, 1962; Tyler, 1949; Office of Basic Education Commission of Thailand, 2010).
2. Theories, documents, and related literature in Systems Thinking were studied (Senge, 1994; Senge, 2000; Richmond, 2000; Anderson and Johnson, 1997). The problem of knowledge management among teachers of Grade 9 was studied by using a questionnaire. The questionnaire was administered to 84 people teaching Grade 9 during 2013 academic year in 14 Extensional Opportunity Extension Schools, under the jurisdiction of Surin Primary Educational Service Area Two. Also in-depth interviews were done with 14 teachers. Data from the questionnaires were analyzed by calculating the mean, percentage, and standard deviation. Data from the interviews were analyzed using Content Analysis.

Phase 2: develop tentative curriculum

1. The curriculum development phase consisted of developing the rationale and approach, objectives, course description, learners' outcomes, structure of the content and lessons, learning activity management, learning media and source management, and measurement and evaluation.
2. The documentation of curriculum development consisted of a handbook for using the curriculum and lesson plans.
3. The tentative curriculum was evaluated by seven experts for evaluating the appropriateness of curriculum.
4. The tentative curriculum was piloted with 30 students in a single Grade 9 classroom.

Phase 3: the implementation of the curriculum

1. The design used in this phase of study was the quasi-experimental design as one-group time-series design (Campbell and Stanley, 1969) (Table 1).

O_1 O_2 O_3 O_4 refers to the test performed before receiving the knowledge management instruction (pretest). X refers to the knowledge management instruction by using the curriculum for enhancing the students' system thinking process, consisting of 20 lesson plans, over 40 h of instruction time. O_5 O_6 O_7 O_8 refers to the test performed after instruction (posttest).

Procedure: the researchers first seek permission from the Director of Ban Phon Kroke School to do do the study. The pretest used a Systems Thinking Process test developed by the researchers. Four

Table 1. The research design.

Pretest	Treatment	Posttest
O_1 O_2 O_3 O_4	X	O_5 O_6 O_7 O_8

tests were administered one week apart. The curriculum was implemented using 20 lesson plans over 40 h of instruction. Behavior of students was observed during every lesson plan. The posttest was administered using the same Systems Thinking Process test with the same intervals of one week per test. To guard against the students remembering the pretest questions and the practice effect, the test included parallel construction in which the questions were not in the same sequence.
2. The study of students' opinion on curriculum as expressed in the questionnaire.

Instruments

The instruments using in this study included:

1. A questionnaire asking about problems in knowledge management.
2. An interview form asking about problems in knowledge management.
3. The curriculum used in the Grade 9 classroom for enhancing the level of systems thinking. It consisted of a handbook for curriculum usage, and lesson plans.
4. The Systems Thinking Inventory, which included:

a. the Behavioral Observation Form indicating one's competency in using the Systems Thinking Process, as Rubric Score, used for observing every behavioral lesson plan
b. the Systems Thinking Process test as an essay test including 4 items,
c. the questionnaire used to gauge students' opinions on studying the curriculum.
d. The Learning Diary Record.

Data Collection

The study began with a review of literature, documents, promotional literature and other sources for the development of a curriculum that would enhance students' skills using the Systems Thinking Process. From this, a draft curriculum was created, which was shared with seven noted experts in the field. At the same time, issues in knowledge management, which came up, were addressed in the form of a questionnaire and script for conducting interviews with teachers of Grade 9. Finally, the curriculum was piloted in the selected Grade 9 classroom in Surin Educational Service Area Two, in Ban Thasila School. The study was then conducted with a classroom of 32 students in Ban Phon Kroke School, in Surin Educational Service Area Two during the first semester of the 2013 academic year. This curriculum was administered for 20 weeks, over a total of 40 h of instruction, following the standards of one-group time-series design (Campbell and Stanley, 1969). At the end of instruction and posttest, students were asked to complete a questionnaire on the curriculum.

Data analysis

Basic statistics were collected from the pretest ad posttest scores: percentage, mean, and standard deviation. The tests were assessments of students' competency in using the Systems Thinking Process. Pretest and posttest scores were further compared by using the statistic F-test, calculated by analyzing the one-way Repeated Measure ANOVA, category analysis and content analysis. Students' responses to the questionnaire were scored based on a 5-point Likert scale. This was also subjected to measurements of the mean and standard deviation, and then tabulated.

RESULTS

The problem of Knowledge Management of teachers teaching Grade 9

The problem was in "High" level. ($\overline{X}$ = 3.82 S.D. = 0.39). Interviews with teachers resulted in the following recommendations:

1. There should be continuous training or practice in systems thinking for students.
2. Work projects that are complex, encourage systems thinking and can be evaluated and assessed should be taught.
3. Media and materials that facilitate students' learning should be provided
4. Lessons should present problems with more than one solution, so students could think in various ways and apply these skills in their daily lives.

These recommendations were incorporated into the curriculum design by the researchers.

Assessing the developed curriculum

The panel of experts who assessed the tentative curriculum evaluated its appropriateness at a "High" level ($\overline{X}$ = 4.37 S.D. = 0.39). The developed curriculum for enhancing systems thinking process consisted of the following.

Rationale and approach

1. Knowledge Management was a student-centered activity based on self-directed learning.
2. The training viewed 4 levels of the problem or situation including: 1) the incidence level, 2) the pattern level, 3) the structure level, and 4) the mental model level.
3. The training or practice involved determination of the problem, variables related to the problem, a written chart indicating observed student behavior, designing a chart of the causal cycle, presentation of the findings, and the evaluation of the results of instruction in systems thinking.

4. The development of skill in systems thinking for groups and public presentation.
5. Controlling the learning climate and source management facilitating the students' learning.

Objectives

1. To train the systems thinking processes of students from situations and problems relevant to local contexts.
2. To show competence in viewing situations or problems in 4 levels overall.
3. To show competence in applying systems thinking in daily life.

Course description

The Crisis in Our Locality for Enhancing Systems Thinking (1 credit; 40 h): The study, searching, and analysis of crisis problem in strayed elephant, the problem of demolished soil, stone, and mineral, the disaster from agricultural chemicals, and the problem of ecological system in Moon River Basin and Tammoon Forest by using System Thinking Process, Group Process, and Information Searching in order to obtain knowledge as well as comprehension and competency in using the Systems Thinking Process for determining the problem, specifying the variable relating to the problem, writing the chart indicating the behavior, writing the chart of causal cycle, presenting the findings of Thinking Process, evaluating the Thinking Process, being competent in practicing the activity for practicing the Systems Thinking Process as well as desirable characteristic.

Learner outcomes

1. The students obtained knowledge and comprehension in such problems as strayed elephants; demolished soil, stone, and minerals; ecological consequences of agricultural chemicals; and the problems of Mon River Basin and Tammoon Forest.
2. The students were competent in using Systems Thinking Process for analyzing problems and applying them in their daily life.

The content and learning unit

The content and learning unit is organized into 4 learning units as follows: Learning Unit 1: "Strayed Elephant"; Learning Unit 2: "Demolished Soil, Stone, and Mineral"; Learning Unit 3: "Disaster from Agricultural Chemicals"; Learning Unit 4: "Problem of Ecological Systems in Moon River Basin and Tammoon Forest".

Learning activity management

The management of the learning activity included the following five steps in sequence as follows:

1. The situations stimulating the problem were provided for enhancing the ability of students to be able to determine the problem, analyze the context of topic they were thinking by using various kinds of media for encouraging the students to have cognitive dissonance.
2. The goal of comprehension refers to making the students understand the relationship between the problem and factors, the potential body of knowledge or rationale relating to brainstorming and discussion, and the search for empirical data as well as academic information.
3. A chart is written that refers to each student's class presentation in small groups. The chart and presentations show the determination of variables relating to the problem, graphs to indicate one's behavior during the time schedule, and a diagram of causal cycles.
4. These presentations of findings and conclusions make the students to have an opportunity to present their work together. Discussions show how they found the solutions of the problem. Throughout, the teachers were only the leaders of discussions and helped point out aspects of the presentation which should be considered. Then, each student was allowed to consider one's own thinking process in order to improve again.
5. The performance assessment is an initial self-assessment of individual as well as group performance. Then, teachers and students collaborated in evaluating their performance together.

Management of media and learning media

The learning media used varied and were relevant to the objectives and content of activity management. Media that would stimulate the students' interest and enhance their systems thinking process included, for instance, videotape, additional books, the prepared Knowledge Document, brochures, worksheets, activity sheets, photographs, problem situations from published sources.

Measurement and evaluation

For assessment and evaluation during instruction, an authentic assessment was determined, for instance, through the observation of student behavior which can

indicate individual competency in using the Systems Thinking Process, followed up by the interview and assessment of group presentation. After completion of instruction, the measurement of evaluation was determined by using the Systems Thinking Process test in the vendor's package.

The result of curriculum implemented

Qualitative assessment is based on the result of observation of students' behavior indicating students' competency in Systems Thinking Process.

According to these observations, the analysis of findings from student interviews and learning diaries kept by students, the students had knowledge and comprehension of the problems, competency in using a process of systems thinking for determining the problem, presenting the guidelines for solving the problem, and applying these solutions in their daily life. They had the highest ethics, morality, and all the desirable characteristic which will help them accomplish the learning achievement of the subjects. Every student was able to determine the problem, specify the variables relating to the problem, create a chart indicating patterns of behavior relating to the problem and causal loop, present the outcome of their thinking process, evaluate the thinking process, and reflect upon each of their thinking correctly regarding the problem.

The in-depth interviews proceeded as follows:

1. The students could learn from instructional media and sources that existed close to them. As a result, they were able to determine every aspect of the problem. The size of images was always appropriate, various, and interesting.

2. The students in each group brainstormed, collected data, and searched for information in order to analyze the problem, its causes, and find guidelines for problem solving from various sources of information. They were able to produce a beautiful pamphlet of the species of trees in Tammoon Forest as well as fish species in the Moon River. They learned from meaningful activities, and became aware of the problems. Each group of students had interactions with each other. There was a good learning climate in the classroom. They knew the real problem situation fully.

"I would study and search for additional knowledge."
"I would search for additional information from the Internet."
"It is necessary to plan and design before performing the real practice."

3. The students created a chart indicating patterns of behavior relating to the problem and a causal loop. Most of the students could write the chart correctly as well as decorate the pictures beautifully and appropriately. Each problem issue was connected. Every problem issue was covered. When each student's performance was collaboratively analyzed into the group performance, every group was able to perform it. In addition, they covered both the same problem issues, and some different problem issues.

"Our group collaborated in planning, designing, analyzing, and discussing in order to write the chart."

4. The presentation of the group's work was both performance and a set of conclusions on many viewpoints. However, as we listened to the others' opinions, the students from each group could analyze four levels of the problem. At the level of mental representation, they were able to give their opinions according to the guidelines for prevention of and problem solving in a variety of ways. They provided many kinds of media and techniques for their presentation, for instance, pictures and Power point.

"There is a team working systematically."

5. Evaluation of performance. The students performed their own authentic assessment by reflecting upon their thinking, and giving additional opinions on their teacher's activity management, whether their learning was flexible, and whether they can associate their learning, and integrate every learning substance into their daily lives.

"It causes the students to think about solving different problems in daily life systematically which could be used for real application."
"We could search for various solutions, and be enthusiastic for learning."
"The evaluation is performed by every group of students. The creative viewpoint is useful for learning."
"I create my Art Performance from sand with all of my potentiality."
"I like this kind of assessment because I could know my assessment performance immediately, and it is fun as well."
"The teacher's activity management could help me to practice my systems thinking process, and obtain the skills in observing, analyzing, presenting my performance, and working in a team."
"I would apply this knowledge in my daily life."

Quantitative data were derived by using the test. The comparative findings of competency in using the Systems Thinking Process are shown in Table 2.

According to Table 2, the comparison of pretest and posttest scores showed that there were significant differences at .01 level.

Table 2. The mean, standard deviation, and f-test of competency score in using the systems thinking process

Testing	Number	Full score	$\overline{X}$	S.D.	F	Sig
Pretest	1	60	21.34	5.46		
	2	60	21.56	5.49		
	3	60	21.59	5.46	67.026	.000**
	4	60	21.59	5.53		
Posttest	5	60	49.81	7.37		
	6	60	50.06	7.28		
	7	60	49.62	7.48		
	8	60	49.62	7.20		

** Significant at .01 level.

($\overline{X}$)

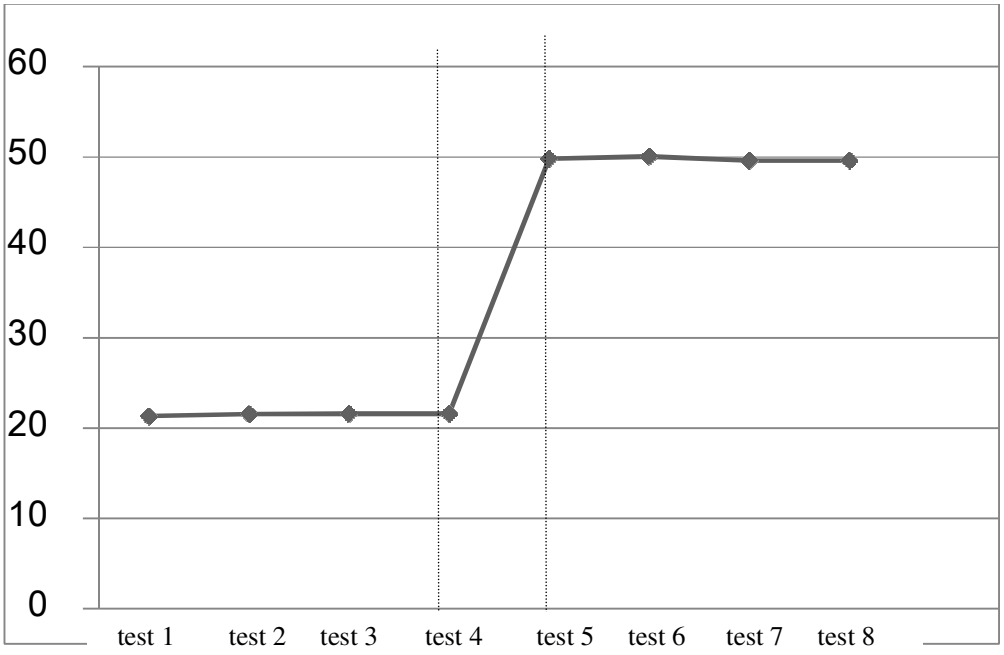

Figure 1. Comparison of the mean of students' competency in using Systems Thinking.

Mean values of students' competency in using the Systems Thinking Process are presented in Figure 1.

According to Figure 1, the mean scores of students' competency in using the Systems Thinking from the 1-4 pretest were nearly the same (21.34, 21.56, 21.59, 21.59) There were differences in mean values between the 4th (21.59), and the 5th tests (49.81). In addition, the mean scores of the four posttests (49.81, 50.06, 49.62, 49.62) were nearly the same.

The researchers then tested the paired comparison whether differences in pairs were significant. It was found that the differences were significant in the mean values at .01 level, from 16 pairs. The other 12 pairs were not significant.

The result of students' opinion on studying the curriculum rated its appropriateness at a "High" level ($\overline{X}$ = 4.32 S.D. = 0.25). This rating of the appropriateness of the curriculum was at the "High" level in every aspect. The mean values were as follows: measurement and evaluation of learning achievement ($\overline{X}$ = 4.40 S.D. = 0.34), learning media and source ($\overline{X}$ = 4.35 S.D. =

0.40), learning activity management ($\overline{X}$ = 4.30 S.D. =0.32), and content of curriculum ($\overline{X}$ = 4.25 S.D. = 0.35).

DISCUSSION AND CONCLUSION

In developing the curriculum for enhancing the Systems Thinking Process for Grade 9 Students, the researcher found that there were issues discussed as follows:

1. The findings from observation of behavior showed that the students obtained sufficient knowledge and comprehension in working on their problems. They were able to use their Systems Thinking Process in determining the problem, presenting guidelines for problem solving, and applying lessons in their daily lives. They had ethics, morality, and all of the desirable characteristics which could accomplish the course objective. Every student could determine the problem, specify the variables relating to the problem, write diagrams or charts indicating the behavioral pattern of the problem as well as a causal loop, present their thinking processes and reflecting correctly their approach to the problem. In a Systems Thinking Process, the most important issue is to think and understand the whole system or thinking process. Therefore, the knowledge management has to be systematic and that the process must be given highest importance (Senge, 2000). "Systems thinking is a methodology for visualizing interrelationships within a complex system. Given that the focus of interdisciplinary inquiry is to understand the portion of the world modeled by complex system." Nowell (2001) and Repko (2008) found that a system map is a highly useful analytical tool that can help one visualize a system or problem as a complex whole. This has been supported by Toomtong (2010) in "Development of Knowledge Management Model for Developing the System Thinking Process in Mathematics, Class Level 4," in which he found that the developed model for knowledge management was effective according to the specified criteria. Dawidowicz (2011) found that an understanding of and application of systems knowledge has been studied in various business, government, and education environments. However, it is unclear what people at large know about systems thinking, where they gained their knowledge, and how important they consider systems thinking in their decision-making processes. This first phase of a 2-year exploratory study considered these unknowns to identify any need for teaching systems thinking and how to best teach it if appropriate. Results indicated that although the 172 respondents agreed making decisions using systems thinking is important to 79.7% of decisions made and approximately half believed they understood the meaning of social systems and application of systems thinking to decision making, most demonstrated no or limited understanding of both. Finally, most participants' latently gleaned impressions of systems and systems thinking were gained through informal experiences that had occurred since completing their secondary school education.

Hung (2008) described systems thinking as an essential cognitive skill that enables individuals to develop an integrative understanding of a given subject at the conceptual and systemic level. Yet, systems thinking is not usually an innate skill. Helping students develop systems thinking skills warrants attention from educators.

2. The comparative findings of competency used in Systems Thinking Process: There were significant differences in students' competence in using their Systems Thinking Process at .01 level. According to the findings, it could be seen that the developed curriculum for enhancing the Systems Thinking Process could be used for developing the knowledge management for enhancing the Systems Thinking Process. This is because the researchers systematically developed the curriculum for enhancing the Systems Thinking Process based on the rationale, theory, and related research literature with clear steps. All kinds of instruments were investigated by experts for their quality.

The management of active learning was provided for enhancing the students' competency in using the Systems Thinking Process for solving the specified problems or situations very well. Learning activity management was used by the researchers in the training process. This approach was supported by Senge (2000), who described Systems Thinking Process as an in-depth systematic analysis including: 1) the event level, 2) the trend and pattern level, 3) the structure, 4) the mental model level. The findings of the use of activity management for enhancing the Systems Thinking Process were that students were better able to use the higher level of Systems Thinking Process during the posttest more than the pretest at .01 significance level. This finding was supported by Roma (2008), who found that this implementation could provide the curriculum in Natural Science for Class Level 3 students. Supplementary documents for curriculum evaluated by a panel of experts included were qualified to be used. It was found that the students had better learning achievement at .01 significant level. Assaraf and Orion (2005) looked at the development of systems thinking skills at the junior high school level. The sample population included about 50 eighth-grade students from two different classes of an urban Israeli junior high school who studied an earth systems-based curriculum that focused on the hydro cycle.

The research combined qualitative and quantitative

methods and involved various research tools, which were implemented in order to collect the data concerning the students' knowledge and understanding before, during, and following the learning process. The findings indicated that the development of systems thinking in the context of the earth systems curriculum consisted of several sequential stages arranged in a hierarchical structure. The cognitive skills that are developed in each stage serve as the basis for the development of the next higher-order thinking skills. The research showed that in spite of the minimal initial systems thinking abilities of the students most of them made some meaningful progress in their systems thinking skills, and a third of them reached the highest level of system thinking in the context of the hydro cycle.

Two main factors were found to be the source of the differential progress of the students:

(a) the students' individual cognitive abilities, and (b) their level of involvement in the knowledge integration activities during their inquiry-based learning both indoors and outdoors.

3. The findings of students' opinion on curriculum: The students answered a questionnaire regarding their opinions about the value of studying the curriculum for enhancing the Systems Thinking Process. Their scores were at the "High" level in every aspect. The highest average level was the question on measurement and evaluation in learning achievement. These high results are a product of the opportunity provided by the researchers for students to participate in evaluating their learning achievement. Each group evaluated each other group's performance by reflecting as an authentic assessment. This approach was supported by Mueller (2014), for whom "authentic assessment is a form of assessment in which students are asked to perform real-world task that demonstrates meaningful application of essential knowledge and skills."

Furthermore, the researchers determined the evaluative criteria as rubrics precisely in evaluating students' behavior to indicate their competency in using the Systems Thinking Process. This in turn could help students to see guidelines for developing one's quality work practice or performance, to be given feedback on their strengths, weaknesses, and what should be improved in their work piece, and then to be able to judge the quality of work piece reasonably in both their own work and others. It could reduce the teachers' time in evaluating their students' performance since the students would evaluate their own performance and that of others. It was flexible for various characteristics of teachers and students. Moreover, it could help the students to know what is to be learned. Corroboration can be found in the work of Limcharoen (2009), in which the experimental group students had their opinion of the supplementary curriculum at a "Good" level.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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