Research Article

EFFECTS OF COLLABORATIVE INQUIRY ON COLLABORATIVE PROBLEM SOLVING ABILITY OF LOWER SECONDARY SCHOOL STUDENTS

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Abstract

Collaborative problem solving (CPS) ability refers to the capacity of an individual to engage and attempt to solve problem with group members collaboratively. The crucial features of teaching strategies enhancing CPS ability should consist of communicating, managing conflict, organizing a team, building consensus, and managing process. Collaborative inquiry (CI) is claimed to be effective to enhance students' CPS ability. However, the research on effects of CI is still limited. This study aimed to study CPS ability of students who learned science through CI and compare with students who learned science through 5E instructional model by using quasi-experimental research. The samples were 37 students who learned science through CI. 3-level scoring rubrics were used to collect students' CPS ability and then analyzed by using mean and SD. Effect size and independent sample t-test were used to compare CPS ability between two mentioned groups of students. The result revealed that students who learned science through CI had higher mean score of CPS ability than another group at .05 level of significance and their CPS was considered as high level. They deeply discussed the problem situations in which help them to solve problems efficiently. They were encouraged to give feedback about task-doing that covered the actual performance. From these results, teachers should consider the students' roles for completing tasks collaboratively. Further studies may explore the effect of teamwork which has relevant features to CI and effects of gender and learning styles on CPS.

Keywords: Collaborative Inquiry, Collaborative Problem Solving, CPS, Collaboration

Introduction

The challenge of education in 21st century is to improve students' outcomes and be the effective people in the interconnected world (Partnership for 21st century skills, 2007). Problem solving which aims to find the possible solutions (Miri, David, & Uri, 2007; Partnership for 21st century skills, 2007; Sirichaisin & Wattanatorn, 2018) and collaboration which aims to support the collaborative environment during finding the solutions in team (Partnership for 21st century skills, 2007; Hesse et al., 2015) are both essential ability of collaborative problem solving (CPS) ability which should be prepared for students since they were in school (Kivunja, 2014). CPS requires individual to engage in a process of problem solving with two or more people by sharing knowledge, understanding, skills, and efforts to accomplish the solutions.

According to CPS Framework proposed by OECD (2013a), there are three core competencies of CPS; 1) establishing and maintaining shared understanding, 2) taking appropriate action to solve the problem, and 3) establishing and maintaining team organization. All of them are comprised and led students to manage and handle the problems in the situations with peers collaboratively and effectively. However, not all teaching strategies can support students to develop their CPS's core competencies.

In science classroom, one of the most effective widespread teaching strategies is BSCS 5E instructional model (Bybee et al., 2006) which includes of engagement, exploration, explanation, elaboration, and evaluations phases. In Thailand, this contemporary teaching model has been promoted by The Institute for the Promotion of Teaching Science and Technology [IPST], one of the policy-level organization, as a teaching strategies in science classroom. Although, here were several research applied 5E alone to enhance students' collaboration and problem solving skills, these abilities were not developed effectively (Duangkaew, Pibranchon, & Sirisawat, 2016; Salin, Sirisawat, & Pibanchon, 2019).

Teaching strategies which are able to promote CPS of students should address communicating, managing conflict, organizing a team, building consensus, and managing process OECD (2013a) and should be characterized from the dimensions of problem solving and collaboration. Collaborative inquiry (CI) proposed by Chang, Sung, and Lee (2003) is able to support those criteria in terms of providing students opportunity to do activities with their group members, give reflection and feedback about their group performance in order to answer the key questions (Bray, Lee, Smith, & York, 2000; Jackson & Street, 2005; David, 2009; Stoll, 2010).

Four steps of CI (Chang, Sung, & Lee, 2003) are anchoring and planning, individual inquiry, collaborative inquiry, and concluding group's results. They explored the effects of this model to learning process of undergraduate students. Results showed that they had active learning process including active in discussing, sharing ideas, and developing their understanding. Hence, CI is able to enhance CPS. However, there is no results of CI enhancing students' CPS ability and science-based CI were not addressed from previous research.

Comparing these mentioned models, the four steps of CI alone may not be enough to enhance students' CPS ability. They should have opportunities to practice the application of their existing knowledge to other related situations in order to develop their problem solving and collaboration ability. In this case, the elaboration stage of 5E instructional model (Bybee et al., 2006) may provide such opportunity. Therefore, this study aims to explore whether the modified version of collaborative inquiry proposed by Chang, Sung, and Lee (2003) and added the elaboration from 5E instructional model (Bybee et al., 2006) will enhance students' CPS ability.

Research Questions

1. What is the collaborative problem solving ability of students who learned science through collaborative inquiry?
2. Do students who learned science through collaborative inquiry differ in collaborative problem solving ability from students who learned science through 5E instructional model?

Research Hypotheses

1. Students who learn science through collaborative inquiry will have high level of collaborative problem solving ability.
2. Students who learn science through collaborative inquiry will have higher collaborative problem solving ability than students who learn science through 5E instructional model at .05 level of significance.

Research Methodology

Research design

The design of this study was two-group posttest only design and elongated with qualitative data. The student was divided into two groups which were two classrooms. Both of them were conducted the lessons by the first researcher.

Populations and samples

The populations were the lower secondary school students of the Office of Private Education Commission (OPEC) in Bangkok. The samples of this study consisted of totally 72 eighth grade students who were studying in the first semester of the 2016 academic year of a lower secondary school of a private school in Bangkok. The sample were divided into two groups, experimental group was 37 students learned science through CI and controlled group was 35 students who learned science through 5E instructional model.

Intervention

The intervention was collaborative inquiry modified from Chang, Sung, & Lee (2003) and the 5E instructional model (Bybee et al., 2006). The 23-hour lessons consisted of 2 units; separating mixtures and chemical reaction. The modified CI are;

1. Anchoring and planning – Students individually identify problems and make the hypothesis of the situations given by teacher and making graphic organizers to plan the investigation.
2. Individual inquiry – Students individually search the information about the investigation, then revise the previous graphic organizers based on information they found and make scientific explanation.
3. Collaborative inquiry – Students in team share the information they found and revised graphic organizers using collaborative learning techniques.
4. Concluding group's results – Students in team make final graphic organizers based on team discussion, then revise scientific explanation they made.
5. Elaboration – Students apply knowledge to other related advanced situations, share final graphic organizers to public, and assess their investigation.

Data collection tools

To collect CPS, this study used the observation form of CPS ability that was a 3-point scoring rubrics. It consisted of 3 competencies of CPS mentioned in PISA 2015 CPS framework (OECD, 2013b) including 1) Establishing and maintaining shared understanding; 2) Taking appropriate action to solve the problem; and 3) Establishing and maintaining team organization.

Data collection methods

Observation was the major method of data collection. Four observers including the first researcher and 3 trained assistants separately observed, recorded student behavior and scored students' CPS using the CPS rubrics. The observers scored 1, 2, or 3 depending on students' level of performance while doing the group activity or experiment with their group members. The total score summarizing from each competency showed students' CPS ability which divided into three levels; high (2.34 - 3.00 total scores), moderate (1.67-2.33 total scores) and low (1.00-1.66 total scores).

The two scenarios of CPS tasks were set according to the unit of separating mixtures and chemical reaction which were addressed in grade 8 science textbook. The scores of two scenarios were counted and summarized as the score of CPS ability. Each components contains 6 total score, 3 from each scenario. However, the component of "Modifying the action plans or role (only when facing unexpected problems)" will be counted when it occurs.

The inter-rater reliability was determined by correlation coefficient among 4 observers; 1 researcher and 3 assistants, was considered. The inter-rater reliability was between 0.98-1.00 which meant that each pair of the observers were high reliability.

Data analysis

In order to answer CPS ability of students who learned science through CI, mean and SD were used to explain their CPS ability. In contrast, the comparison of CPS of students who learned science through CI and 5E instructional model were analyzed using effect size (Cohen, 1988) and independent sample t-test.

Results

CPS Ability of Students who Learned Science through CI

The analysis of collaborative problem solving ability was based on the data collection from the observation form of collaborative problem solving ability that consists of three competencies. The total score of each competency are 3. The score are all considered as high level. The mean score of total score was 2.70 (SD=0.54). The highest mean scores among three competencies were establishing and maintaining shared understanding (M=2.75, SD=0.48). The mean score of each components are presented in table 1.

Table 1: The CPS ability score of experimental group

Assessed components	Initial Score (Mean (SD))		Final score (Mean (SD))
	Scenario 1*	Scenario 2*	
Competency 1; Establishing and maintaining shared understanding			
1. Understanding the problems and task	2.81 (0.61)	2.73 (0.45)	2.77 (0.43)
2. Regulating the interaction among group members that related with the problem solving in tasks without wandering off	2.83 (0.60)	2.62 (0.64)	2.73 (0.53)
Summary of Competency 1			*2.75 (0.48)*
Competency 2; Taking appropriate action to solve the problem			
1. Considering the strength and weakness of group members during task performance	2.44 (0.64)	2.35 (0.63)	2.40 (0.57)
2. Following the procedure of given or planned problem solving tasks	2.86 (0.58)	2.97 (0.16)	2.92 (0.28)
3. Communication during task-doing for successive problem solving and task completion	2.83 (0.60)	2.86 (0.35)	2.85 (0.36)
Summary of Competency 2			*2.72 (0.48)*
Competency 3; Establishing and maintaining team organization			
1. Modifying the action plans or role (only when facing unexpected problems)	3.00 (0.00)	-	3.00 (0.00)
2. Giving feedback and reflection about the success of the group	2.61 (0.84)	2.38 (0.79)	2.49 (0.77)
Summary of Competency 3			*2.55 (0.74)*

*Scenario 1 = separating mixtures, scenario 2 = chemical reaction

The seven components of CPS ability that mentioned above were considered two scenarios. However, the component of modifying the action plans or role (only when facing unexpected problems component) was assessed only in scenario 1 separating mixtures. The procedures of separating mixtures they set were not proper to the mixtures they observed, so they need to revise their previous procedures before continue their experiment. The further descriptions of each assessed component were presented below:

The first competency "Establishing and maintaining shared understanding" was considered as high level. Considering the first assessed components (understanding the problems and task; M=2.77; SD=0.43), most of students were eager to revise the task procedures with their members throughout the data collection phase. While the second assessed components (regulating the interaction among group members that related with the problem solving in tasks without wandering off; M=2.73; SD=0.53), students sometimes discussed the task without wandering off.

The second competency "Taking appropriate action to solve the problem" was considered as high level. Considering the first assessed components (considering the strength and weakness of group members during task performance; M=2.40; SD=0.57), most students participated in giving the information about their strength and weakness, and they were eager to ask questions about the strength and weakness information of their group members in order to assign the appropriate roles. While the second assessed components (following the procedure of given or planned problem solving tasks; M=2.92; SD=0.28), most of them followed the group's action plans or procedure of given task throughout completing the task intentionally. The last assessed components (communication during task-doing for successive problem solving and task completion; M=2.85; SD=0.36), most students discussed about the topic that related with the task but some of them participated with their peers only when they were encouraged.

The third competency "Establishing and maintaining team organization" was considered as high level. Considering the first assessed components (modifying the action plans or role (only when facing unexpected problems); M=3.00; SD=0.00), there were 10 students out of 37 students that confronted the problem during completing the separating mixtures tasks. They need to revise procedures of separating mixtures that they planned properly before continue their experiment. Each member recognized the modification of the action plans or role in order to eliminate the obstacles during task performance and eager to follow the modified plan. The second assessed components (giving feedback and reflection about the success of the group; M=2.49; SD=0.77), most students were eager to participate in giving feedback and reflection that related with role assignment and group performance.

Comparative Analysis of CPS Ability of Students who Learned Science through CI and Students who Learned Science through 5E instructional model

Considering the total score of 3 competencies, there was a significant difference in the scores for CPS of students who learned science through CI (M=2.70, SD=0.54) and students who learned science through 5E instructional model (M=2.21, SD=0.69); t(47.983)=3.938, p=0.000. Most of students who learned science through CI got high ability while the most of students who learned science through 5E instructional model got high and moderate level. Moreover, the Cohen's d value was 0.71. It meant that there was large effect of the CI over the 5E on CPS.

Table 2: The results of independent sample t-test

		Levene's test for equality of variances		t-test for equality of means					
		F	Sig.	t	df	Sig (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
								Upper	Lower
1st competency	Equal variances not assumed	12.801	0.001	3.099	50.856	0.003	0.348	0.123	0.573
2nd competency	Equal variances not assumed	18.525	0.000	3.061	48.234	0.004	0.307	0.105	0.509
3rd competency	Equal variances not assumed	6.445	0.013	4.346	59.256	0.000	0.648	0.350	0.947
All competency	Equal variances not assumed	18.715	0.000	3.938	47.983	0.000	0.428	0.209	0.647

The first competency was Establishing and maintaining shared understanding. There was a significant difference in the scores for CPS of students who learned science through CI (M=2.75, SD=0.48) and students who learned science through 5E instructional model (M=2.33, SD=0.71); t(50.856)=3.099, p=0.003. Besides the increasing of scores, the qualitative data from the study showed that the most of experimental group student got high ability while the most of control group got high and moderate level. During the activity, the experimental group participated in group communication that related with task in order to revise the task procedure without wandering off. Whereas some members of control group participated in group communication in order to revise the task procedure.

The second competency was Taking appropriate action to solve the problem. There was a significant difference in the scores for CPS of students who learned science through CI (M=2.72, SD=0.48) and students who learned science through 5E instructional model (M=2.35, SD=0.67); t(48.234)=3.061, p=0.004. The qualitative data from the study showed that the most of experimental group student got high ability while the most of control group got high and moderate level. During the learning activity, the experimental group participated in asking questions or giving useful information that related with the strength and weakness of group members in order to assign the appropriate roles. Whereas the control group rotated their roles without considered the strength and weakness of group members. The most of control group followed the task procedure but some of them communicated with other members.

The third competency was Establishing and maintaining team organization. There was a significant difference in the scores for CPS of students who learned science through CI (M=2.55, SD=0.74) and students who learned science through 5E instructional model (M=1.95, SD=0.80); t(59.256)=4.346, p=0.000. The qualitative data from the study showed that the most of experimental group student got high ability while the most of control group got all levels. When the unexpected problem occurred, the experimental group recognized the modification of the action plans or their own roles in order to eliminate the obstacles. Moreover, the reflection of the experimental group came from all group members and revised the feedback and reflection before present to the whole class. Whereas the control group did not participate in giving feedback and reflection. The group's reflection came from the presenter's view point and it did not represent the real group performance during the learning activity.

Conclusions and discussions

The characteristic and efficiency CPS ability of students who learned science through CI was considered as high level. The research results were based on research assumption because of these following reasons:

First, the students in CI group shared and exchanged the knowledge that related to the problem situations in which help them to solve problems efficiently. The stage of individual inquiry, each student searched the information that related to the experiment of activity from any resource and planned the procedure by making the concept map or other graphic organizers. These activities encouraged students to do the experiment or activity with the background knowledge that shared with group members and solved the problem successfully. This results is congruent with Engelmann and Hesse (2010) who claimed that the computer-supported collaborative learning (CSCL) with making concept map could enhance students' CPS. The students who learned through CSCL could solve the problems efficiently, completed the task completely, and explain the experiment reasonably.

Second, giving feedback and reflection about the task-doing that covered the real performance and came from group brainstorming, would affect the effective teachers' learning design. This similar to the study of Daigle, Doran, & Perdue (1996) in which claimed that efficient students' learning would happened when they joined activity together in order to explain, and develop the strategies to solve the problems through giving feedback and reflection with their groups or whole class.

Moreover, there was the notice about students' quality of CPS ability. Their quality depends on the practiced time. They would perform the CPS ability automatically without encouraged from others if they had enough time to practice and understand the nature of problem solving. This research, students were assessed 8 times during eight-week research collection. The results showed that students' mean scores of CPS in 1st, 5th, and 8th week were 2.28, 2.50, and 2.60 out of 3. Similarly, Weber, Lovrich, and Gaffney (2005) claimed that collaboration would enhance successful long-term CPS ability. In addition, emphasized the integration among group members who had specific roles and participated in task-doing with group members in order to solve the problems successfully.

The comparison of CPS ability between students who learned science though CI and 5E instructional model showed that the experimental group had higher ability in CPS than the control group at .05 level of significance. The results are based on research assumption because of these following reasons:

First, making the concept map in order to plan the procedure of the experiment or activity would improve students' CPS ability. For this implementation, students who learned science through CI would search the information from any resources in the individual inquiry stage. They made the concept map before sharing the given information among group members. Therefore, they had enough information to share and discuss with group members during group discussion in the stage of concluding group's results. Otherwise, the students who learned science through 5E instructional model did not make the concept map for planning the task procedure. In fact, they only followed the procedure that planned by teacher. Therefore, the activity did not improve students' CPS as much as it would be. This result is congruent with the study of Engelmann, Kozlov, Kolodziej, & Clarita (2014) in which claimed that the CPS ability level of students who make concept map and could see other group members' concept map during the activity was higher that the CPS ability level of students who only make concept map. It is because seeing others' concept maps was useful for them to develop their concept maps, not only the content, but also the making method. Whereas groups' concept map of students, who made their own concept maps without seeing other concept maps, did not have distinguished view point from another group and their work did not encourage the CPS ability.

Second, the group management effected the CPS ability. The experimental group, students did the activity with their mixed ability group members which managed by teacher. Therefore they hardly ever did the activity with their group members before. During the early time doing activity, they had to adapt to work, discuss, and do the activity with their group members appropriately. Meanwhile the control group, students did the activity with their familiar members so they used to work together frequently more than the experimental group. Similarity, Strough, Berg, and Meegan (2001) claimed that the efficiency of CPS ability based on task and social demands. The problems solving tasks not only came from the cognitive conflict of group members, but also came from the maintaining team organization during doing the tasks. All members could interpret the same situation from their own idea so there were different viewpoints about the same situation. Therefore, if students could handle the different viewpoint problems, they would complete the CPS tasks no matter what the relationship among group members would be.

The last reason, the most of students who learned science through CI repeated their assigned role when they did the activity to complete problem solving tasks. It improved students' working skills that related with their roles and enhanced efficient students' CPS ability. On the other hand, students who learned science through 5E instructional model rotate their roles when they did the activity to complete problem solving tasks. Students had a good opportunity to practice any works in each role but they could not had a special skills or specific roles that they were good at. Therefore, they could not do their assign roles as good as they could. However, the result was different from Baker and Bielaczyc (1995) who claimed that the missed opportunities in CI was the repeated role assignment during doing the tasks. Moreover, each student did not had the same ability and learning outcome level do they could not had a deepening understanding when learning through CI.

Recommendations

Recommendations for application of this study

Students in each group can manage their role assignment by themselves appropriately because they are the parts of group members who do the activities together, especially hands-on activity. This research, teacher determined the roles for students which were team leader, result recorder, presenter, and equipment administrator but students assigned the roles for members by themselves. We found that there are more than the roles that determined by teacher such as timekeeper and coordinator. Student who took part as a team leader could be either time keeper or coordinator. By the way, the purpose of determining four roles above by teacher was to let students practice the skills that important when they learn science in school. If they would be good at those skills, they would have been adapted and applied to other situations appropriately.

Recommendations for further studies

Collaborative inquiry can develop students' teamwork ability during doing the activity or experiment in science learning. When they work together in their groups, they have to assign the roles with considering the strength and weakness, plan the procedure of the tasks, share opinion, recognize others' idea, and follow group's action plans responsibly. The characteristics that mentioned above are remarkable features of teamwork which could be explored in the further studies.

Due to the diverse roles of team members during completing the task, the differences and diverse abilities of team members are the main factors of accomplishing the task. Moreover, different gender and learning styles of team members are another important factors which should be considered. Further studies may study the factors affecting students' CPS.

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