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DEVELOPMENT OF COLLABORATIVE PROBLEM-SOLVING COMPETENCY FOR STUDENTS THROUGH TEACHING METHOD OF WORKING IN CORNERS IN TEACHING CHEMISTRY AT HIGH SCHOOLS

Do Thi Quynh Mai[1] and Tran Thi Lan Anh[2]
[1]*Faculty of Chemistry, Hanoi National University of Education*
[2]*Masters student course 28 of Faculty of Chemistry, Hanoi National University of Education*

Abstract. Collaborative problem-solving competency is one of the essential competencies, it is the combined competency of individual and social factors, demonstrating the ability to solve problems through team cooperation. With the organization of learning for students to perform group tasks in the corners, teaching methods of working in corners to have many conditions to develop collaborative problem-solving capabilities for students. However, in practice, when applying this teaching method, teachers only focus on designing tasks that fulfill the goal of knowledge and skills without paying attention to developing problem-solving capabilities through collaborative learning. In addition, teachers also face many difficulties in designing tools to assess students' competency. The paper presents principles and processes for designing learning tasks for collaborative learning activities in corner-based teaching methods to develop collaborative problem-solving competency and building its assessment tools for students in high schools.

***Keywords*:** collaborative problem-solving competency, working in corners, teaching chemistry.

1. Introduction

Problem-solving competency is one of the core competencies that need to be formed and developed for learners. In recent years, there are many individuals, organizations, and countries around the world interested in research such as G. Polya [1], Organization for Economic Co-operation and Development (OECD) [2], some countries such as Australia, Singapore, Canada, New Zealand, etc. Problem-solving competency is always valued and useful for looking for a path to development because each individual must always need to solve problems from simple to complex occurring in human life, these problems often exist in specific contexts or situations. Through problem situations, learners will formulate problem detection skills and practical problem-solving skills. However, the problems in practice are often complicated, although many individuals' experiences, knowledge, and efforts are used, if there is no most specific solution, which is the problem of group cooperation to solve, it is very difficult to complete the task set out [3]. Therefore, in learning, it is necessary to have the active and effective participation of two or more students to solve a problem together by sharing knowledge to find effective solutions to solving existing problems. Therefore, the collaborative problem-solving competency was officially included

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Contact Do Thi Quynh Mai, e-mail address: maidtq@hnue.edu.vn

in the 2015 PISA assessment program by the OECD which transfer from measuring the interaction between individuals and problems to measuring the interaction between individuals when they work together to solve a problem. In Vietnam, the 2018 High school program of the Ministry of Education and Training [4] determined that problem-solving competency, creativity competency, and cooperation competency are the common competencies that all subjects and educational activities contribute to form and development. Currently, there are many research projects carried out by authors Vu Phuong Lien [5], Tran Thi Cuc [6], Phan Thi Anh [7], who have proposed measures to form and develop cooperative competency and problem-solving competence using problem-based learning method, integrated topics method applied into teaching chemistry in high schools. However, there are few research projects applying teaching methods to develop collaborative problem solving through the teaching method of working in corners for students in teaching grade 10 non-metallic Chemistry.

There are many ways to form collaborative problem-solving competency for students, in which teaching can be considered the shortest and most important path, especially through the teaching process of Chemistry. Chemistry is an experimental subject, with a lot of knowledge associated with the practice. Working in corners with the strength is the organization of group learning activities in the corners to create diversity to meet the different learning styles of each student. This method has been studied and implemented in teaching in high schools. However, when designing learning activities in groups, the teachers always only focus on designing activities for individuals or groups but do not pay attention to the development of problem-solving competency for students. Therefore, we study the application of teaching methods of working in corners to develop problem-solving competency for students on the principle of content selection and task design in chemistry teaching and build a toolkit of the competency assessment for students.

2. Content

2.1. Collaborative problem-solving competency

2.1.1. The definition of collaborative problem-solving competency

Collaborative Problem-Solving Skills abbreviated as CPS was included in the PISA 2015 assessment program, according to the 2015 PISA competency framework, collaborative problem-solving competency is *the capacity of an individual to effectively engage in a process whereby two or more agents attempt to solve a problem by sharing the understanding and effort required to come to a solution* [2].

According to authors Griffin and Care [8], the difference between independent work and teamwork (collaborative work) is in the interaction, exchange of ideas, common identification of the problem, and unified discussion and individual dynamism/flexibility. Collaborative problem-solving competency is formed based on the exchange of information and experience accumulated through sources of documents and implementation strategies to form common goals that need to be solved.

The ATC21S [9] has introduced a collaborative problem-solving competency structure with two components on "Society" and "Awareness". To solve problems, firstly students must check the problem and become familiar with the information and resources they have when they fully understand the problem and can connect the problem with the existing knowledge, then it needs to plan and set appropriate goals. Students must determine which information needs to learn to explore a broader problem even in the context of ambiguous and confusing information. Students must also decide what resources are involved in order to use and organize information effectively. In the next step, students begin to work on their plans, in which they are encouraged to use a systematic approach. Finally, students can consider and review the ways they have used and test

alternative theories before making a final decision on the finding solution.

In this article, we choose to study the competency structure according to the theory of Assessment and Teaching of 21 Century Skills (ATC21S). Accordingly, the authors Griffin and Care have proposed the structure of the collaborative problem- solving competency including 2 main competencies in short: social competency (including 3 component competencies: participation, opinion, social adjustment) and cognitive competency (including 2 component competencies: task adjustment, learning, and building knowledge).

Thus, the framework of the collaborative problem-solving competency structure is described as follows:

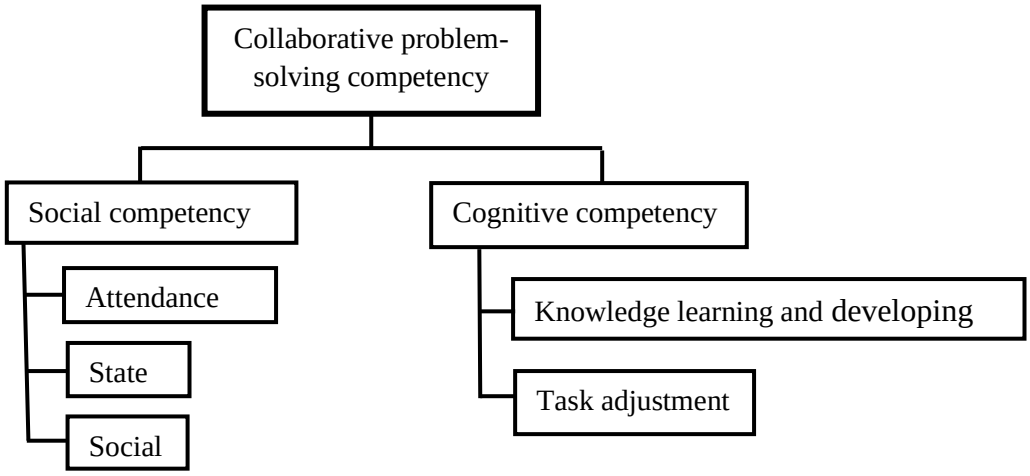


Figure 1. Structure for collaborative problem-solving competency

This structural model shows us a clear view of the components of collaborative problem-solving competency and this is the basis for us to build a criteria framework for evaluating this competency.

2.1.2. Criteria framework of collaborative problem-solving competency

Table 1. Criteria to evaluate collaborative problem-solving competency

Component capacity		**Criteria**	**Expression level**		
			Level 3 (3 points)	***Level 2 (2 points)***	***Level 1 (1 point)***
Evaluation criteria for social capacity					
Attendance	Activity	1. Ability to work in situations.	Ability to work in familiar and unfamiliar situations.	Ability to work in familiar situations.	No or little activity.
	Interaction	2. Interact (respond or cooperate) with other friends.	Take the initiative and promote collaborative activities among team members.	Give feedback, respond to activities in the communication process.	Accept direct and indirect communication.

State opinion	Develop	3. Ability to integrate opinions with other team members.	Use suggestions and contributions of others to come up with feasible solutions.	Adjust and collaborate according to the contributions and suggestions of others.	Review the contributions or suggestions of others.
	Pay attention to other people's feedback	4. Feedback from others about their own comments.	Contribute good and reasonable ideas, are absorbed by members on the basis of knowledge of the recipient.	Comments are carefully reviewed, analyzed, and responded to by members.	Comments are not good, not followed by the team.
Social adjustment (behavior)	Metacognition	5. Ability to evaluate other people's opinions and knowledge.	Agree on a common solution to different comments/ opinions of members based on the ability to analyze and evaluate the right/wrong in those opinions/comments.	There is an attempt to come to a common consensus (but sometimes it succeeds, sometimes it's not because different opinions of the members have not been assessed).	Only reviewing the different contributions of the team, it is not possible to evaluate the opinions of the members.
	Capable of taking full responsibility	6. The sense of responsibility in the team.	Actively and proactively implement the team's responsibilities.	Complete assigned tasks and report to others.	Take on assignments independently with others.
Criteria for evaluating cognitive competency					
Adjustment (implement) tasks	Detect the problem	7. Analyze the situation, identify factors, and information about the problem.	Analyze the situation fully, determine the necessary sequence of each small task.	Analyze some elements of the situation, know how to divide the problem into small but incomplete and their sequence has not yet been	Have not been analyzed the situation yet, only looking at the appearance of the problem.

				determined.	
	Information collection and analysis	8. Search, collect, and find relationships between.	Find, organize, rearrange information, and identify the relationships and patterns between types of information.	Have searched and exploited information, connected information with each other, but incomplete.	Realize the need for more information, focus on separate information.
	Problem-solving plan and implementation	9. Plan to implement and be able to perceive the role of the actions.	Set an action plan with possible solutions in which the causes and results of actions are realized and expected, and the problem is thoroughly resolved.	There is a plan with sequential actions, expected results of the actions, but planning with incomplete or unfeasible solutions, problem-solving is not thorough.	There is no specific feasible plan, only implementing actions, testing the solution randomly but not aware of the impact of the action.
Knowledge learning and developing	Review and adjustment	10. Ability to form and develop knowledge.	Re-evaluate the problem, restructure into general knowledge.	Re-evaluate the problem, from which to draw general but incomplete knowledge.	Have not yet drawn general knowledge from the problem.

2.2. Application of teaching methods of working in corners to develop the collaborative problem-solving competency

2.2.1. Principles of designing learning tasks to develop collaborative problem-solving competency for students

To develop the collaborative problem-solving competency, students must work in corners and rotate corners in groups, not individually. The design of the tasks should be based on the following principles:

Principle 1: Tasks in the corners must be organized to solve a complex problem that requires the participation of team members.

Principle 2: Tasks in the corners must be organized in the form of open questions/exercises with practical contents in order to require students to solve problems together.

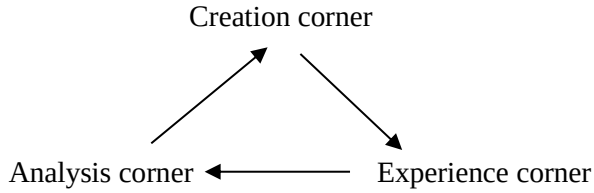
Principle 3: Tasks in each corner need to match the time spent for group activities so that all members of the group can think and discuss together to come up with many suitable and optimal solutions and options.

In addition to the above 3 principles, it can be seen that in practice, class time is often limited, so in order to have enough time for problem-solving activities, the teacher can design 3 corners (such as analysis corner, experience corner, and the creation corner, etc.), and the application

corner is often difficult for students because they have not learned new knowledge in the lesson, therefore, they can transfer the tasks in the application corner into knowledge consolidation activities after acquiring knowledge from other corners.

2.2.2. Analysis of the example of developing collaborative problem-solving competency through teaching method of working in corners

When teaching Lesson 23: *Hydrogen chloride - hydrochloric acid and sodium chloride* - Chemistry 10 Basic programs, the class can be divided into 03 groups. Students will perform the task in each corner and conduct rotation in all 3 corners.



- Creation Corner: Students introduce the roles of hydrogen chloride and hydrochloric acid.

- Experience angle: Students conduct experiments on the preparation and solubility testing of hydrogen chloride and experiment on the chemical properties of hydrochloric acid from which to conclude about the properties of these two substances.

- Analysis corner: Students use textbooks, research, and present physical properties, chemical properties, and methods of hydrochloric acid preparation in the industry.

Creation corner (15 minutes) **"Introduction"**
1. Objective: To learn about the physical, chemical properties, how to prepare and apply hydrogen chloride and hydrochloric acid through the pictures provided by the teacher. *2. Tasks*: To use textbooks and tablecloth techniques to complete the following study sheets: Arrange pictures and write comments (captions) on them under the theme "Our Features" *Suggestions:* Please refer to the textbooks and documents provided by the teacher to get the best caption for each figure from (1) to (6), write the chemical equation in the figure (7), (8), and conclude about the chemical properties of hydrochloric acid.
Creation corner support sheet – **"Introduction about hydrogen chloride and hydrochloric acid"**
Suggestion: Based on pictures, role-play. (Use the tablecloth technique for informational discussion). - What is "your" name? How was "you" born? (Preparation) - Please describe the physical characteristics of "you"? (Physical properties) - Where are "you" in nature? - List "your" personality (which substances do you play/react to? (Chemical characteristic) - What is the role of "you" in this life?

Thus, at the creation corner, the situation setting for the group: playing the role of HCl, writing comments for each picture to introduce themselves. To complete this task in a not too long time (15 minutes), the group needs to work together to solve.

+ First of all, the group must analyze the situation: based on the support sheet to determine the information to be searched.

+ Make a plan to divide the content to learn and assign each member to research a part of the content using the tablecloth technique to save time.

+ Based on the analysis of the significance of the pictures from 1 to 8, the members of the group make predictions about whether the picture is about hydrogen chloride or hydrochloric acid, the advantages or disadvantages then compare to the resources and textbooks. Note and answer the questions in the pictures. At the same time, the group must assign members to stick pictures on A_o paper to present the results.

Analysis corner (15 minutes)

1. Objectives: Students apply old knowledge, research textbooks outlining physical properties, methods of preparing hydrogen chloride, stating physical properties, predicting the chemical properties of hydrochloric acid, and writing chemical equations.

2. Task: Students work individually for 5 minutes and write down their answers on paper. Students discuss in the group for 10 minutes and write in the sub-board.

- What is the state, color, odor, density of hydrogen chloride?
- Write 04 chemical equations (different chemical equations in the textbook) proving that HCl is a strong acid?
- Determine the oxidation number of the elements in the HCl molecule, thereby predicting the oxidation-reduction properties of HCl. Write 02 chemical equations to illustrate those oxidation-reduction properties.

At the analysis corner, the problem arises: chemical analysis is based on the oxidation number of chlorines, general properties of strong acids. Like the creation corner, to complete this task in a not too long time (15 minutes), the group needs to work together to solve.

Make a plan to divide the content to learn and assign each member to research a piece of content using tablecloth techniques to save time.

Discuss in groups, agree on ideas, and record in the sub-board.

Experience corner (15 minutes)

1. *Objective:* From the experiments, students mentioned physical properties, chemical properties, and how to prepare chlorine in the laboratory.

2. *Task:* 2.1. Students observe the hydrogen chloride tank and the hydrochloric acid solution for its state, color, and odor.

2.2. From the chemicals that were present, students discussed in groups to draw experiments to demonstrate the strong acidity and reducing properties of the hydrochloric acid solution, the experiment used to identify HCl

2.3. Students do suggest experiments

2.4. Record your results in the blanks on the study sheet

No.	**Name of experiments**		**Phenomenon - Chemical equations - explanation**	**Comments**
1	The solubility of hydrogen chloride in water			
2	Acidity	Litmus		
		Effects with metals		
		Effects with base		
		Effects with base oxide		
		Effect with sodium		
3	Reducibility			

Practice instruction

If students choose any of the following experiments, they should pay attention to how to proceed as follows:

1. Hydrochloric test with water: Prepare 1 small basin of water to add a few drops of litmus to water. Replace the stopper of the HCl container with a button that has a sharp-through tube. Turn the HCl container upside down into the water basin. Observing the phenomenon occurs.

2. HCl solution with litmus purple: take 1 piece of litmus paper and place it on the glass. Put 1 drop of the HCl solution on a piece of litmus paper. Observing the phenomenon.

3. HCl solution reacts with solids (such as iron nails, copper chips, CuO powder, $CaCO_3$ powder, $KMnO_4$ powder ...): Students will take the solids into the experienced tube first (it need to use the glass spoon to scoop a little powder into a dry experienced tube) and then use a dropper to drip the HCl solution slowly into the experienced tube and observe.

Note: If using $KMnO_4$ in experiments, students must use NaOH impregnated cotton on the mouth of the experienced tube

4. HCl solution reacts with other solutions: use a dropper to drip about 1 ml of the experienced solution into the experienced tube, then take the HCl solution slowly into that tube and observe.

At the experience corner, students divide tasks (do experiments, take chemicals, record phenomena), based on observable phenomena that students discuss together to determine the products of the reaction from there, write chemical equations to illustrate the properties of hydrochloric acid.

Thus, under the instruction and support of teachers, students know to share knowledge with others, listen, respect others' opinions, together identify common tasks to be solved and plan development, assign tasks in accordance with each person's ability, respect and perform the group's assignment; know how to present and exchange results with the group members, from which synthesized into the general results of the group. When groups report their learning results to the class, other skills are also developed: Students know how to present their ideas, argue to defend their ideas in front of the class; know how to evaluate each other. Through many times applying corner lessons, the repetition of those expressions has gradually formed for skills of students in terms of collaboration. Besides, the skills of problem-solving competency are also shown very clearly through the results of implementing the tasks. Thus, the use of teaching methods of working in corners contributes to the formation and development of collaborative problem-solving competency for students.

2.2.3. Development of tools for assessing collaborative problem-solving competency through teaching methods of working in corners

To evaluate collaborative problem-solving competency for students, teachers need to base on the manifestations of problem-solving competency. Based on the criteria framework of the problem-solving competency together with the levels, we designed evaluating tools for teachers. Teachers use these tools to evaluate the attitudes and skills of each student in the observed group. The questionnaire was designed with 10 criteria, each criterion has 3 levels: level 1 is low competency, level 2 is medium competency and level 3 is high competency (Table 1).

In addition to using the checklist according to criteria in the process of teaching by working in corners, teachers also combine with the self-assessment of the student's task performance process (Table 2), the evaluation form members of a group (Table 3), and students' products are the results of the problem when performing tasks at corners to determine the problem-solving ability of students.

Table 1. Teacher's questionnaire sheet to evaluate collaborative problem-solving competency

Criteria	Level			How to evaluate
	3	*2*	*1*	
1. Ability to function in situations				Through observation
2. Interaction (feedback or cooperation) with other friends				
3. Ability to integrate ideas with group members				
4. Feedback from others about their own comments				
5. Ability to evaluate the opinions and knowledge of others				
6. High sense of responsibility in the group				
7. Analysis of the situation, identification of factors and information about the problem				Combining product evaluation and observation
8. Search, collection and finding the relationships between information				
9. Planned action and ability to perceive the role of the actions				
10. Ability to form and develop knowledge				

Table 2. Student self-assessment sheet

Criteria	Level 3	Level 2	Level 1
1. Ability to function in situations			
2. Interaction with other friends			
3. Ability to agree on a common solution			
4. High sense of responsibility in the group, effortless to complete the task			
5. Search, collection and finding the relationships between information			
6. Planned action and ability to perceive the role of the actions			

Table 3. Evaluation sheet for group members' activities

No.	Name of members	Highly active	Active	Involved in	Not involved in	Role in group	Task completion	Valued opinion	Total scores
1									
…									

(Click × in the appropriate boxes)

2.3. Pedagogical experiment

By designing tasks of corners under the above principles, we have designed **03** lesson plans and conducted a pedagogical experiment with 2 experimental classes at Phu Ly A High School (class 10A9 - 41 students), Phu Ly B High School (class 10A1- 46 students) in 2019-2020 school year. Due to the large number of students in each experimental class, we chose 2 fixed groups to

observe and evaluate the development of their problem-solving capacity through 3 experimental periods using the teacher's capacity evaluation card. Thus, we observed and evaluated 30 students (4 groups corresponding to 14 students of class 10A9 and 16 students of class 10A1) through 3 lessons. We used those results to analyze and evaluate the development of the problem-solving capacity of students. The result of the criteria evaluation of the problem-solving capacity of students is as follows:

Table 4. Average scoreboard of criteria for teachers to evaluate problem-solving competence of experimental group students

Criteria	The average score of each criterion									
	1	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***10***
1st	1.60	1.63	1.43	1.50	1.53	1.87	1.67	1.63	1.57	1.70
2nd	1.70	1.97	1.63	1.63	1.73	1.97	1.80	1.67	1.83	1.78
3rd	1.93	2.30	1.77	1.80	1.87	2.03	1.97	1.83	2.07	1.97

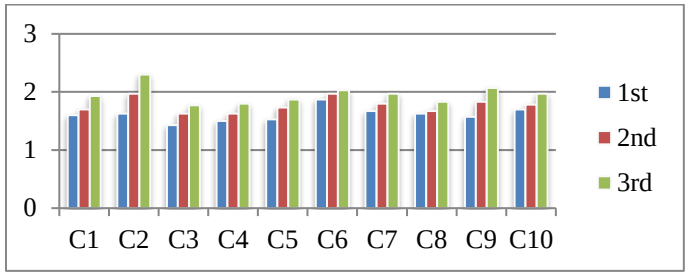


Figure 2. Diagram of the progress of evaluation criteria of problem-solving competence of experimental group

From the above table, we have two following judgments:

Firstly, the criteria of problem-solving competence recorded a markedly increase in a positive direction: In the first stage, the rate of students was mainly at level 1 and 2, in the final stage of the experiment, the rate of students reaching level 1 recorded a gradual decrease, while level 3 increased in all criteria. This partly showed that the problem-solving competence of students was gradually increasing, the development of problem-solving competence for students had a positive effect.

Secondly, the criteria had an uneven increase. Criteria 1, 2, and 5 had a strong increase, criteria 3 and 4 had a moderate increase and criterion 6 had a slow increase. Because these criteria depend on the learning capacity of students, difficult to make progress or having slow progress. Especially criterion 6 was a difficult criterion for students who need a long time of practice because in order to achieve level 3, students must be the ones with good and excellent learning capacity. Criteria 1, 2, and 5 were easy to practice and develop because only students who consciously strive, have an interest, and practice much will become more proficient. Thus, it could be affirmed that students can develop problem-solving competence through the teaching method of working in the corners applied by teachers.

3. Conclusions

After studying and applying teaching methods of working in corners to develop collaborative problem-solving competency in high schools, we find that the effectiveness of applying this method depends on the content selection and requirements set out when designing the tasks in the learning corners practice. These tasks must be complex, requiring students to cooperate, bring into full play the ability and creativity of each member in the group to cooperate in order to solve

the problem posed in a certain period of defined time. Through problem-solving by working together, students will learn problem-solving method, understand the strengths of each member, and have skills to coordinate work and joy of success in learning collaborative problem-solving or practical life.

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