World Journal of Chemical Education, 2018, Vol. 6, No. 4, 190-199
Available online at http://pubs.sciepub.com/wjce/6/4/6

DOI:10.12691/wjce-6-4-6

Evaluate Students' Collaborative Problem-Solving Skills Through an Experiential Approach to Teach Non-metals (A Case Study in High School of Education Sciences and Viet Duc High School in Hanoi, Vietnam)

Vu Phuong Lien[1,*], Tran Thi Van Trang[1], Tran Trung Ninh[2]

[1]VNU – University of Education, Hanoi, Vietnam
[2]Ha Noi National University of Education
*Corresponding author: hssvsvhs@yahoo.com

Received August 02, 2018; Revised September 06, 2018; Accepted September 25, 2018

Abstract Experiential learning aims to enable students to make use of learning tools and materials, and apply their previous understanding to deductive reasoning process to discover new knowledge and solve learning problems. This type of learning also enhances the collaboration among students in their learning tasks so as to develop students' collaborative problem solving. Based on the research of the structure of CPS of high school students by Patrick Griffin & Esther Care (2015) and Kolb's (1984) experiential learning cycle, research group proposes the assessment toolkit, theme building process, and teaching process in teaching properties of nonmetals to develop students' CPS through experiential learning. In order to examine the efficiency of the proposed processes, researchers apply the toolkit and processes to teach two lessons to 50 students in high school of education science. The results illustrate positive changes in students' CPS after two lessons, which suggests high level of reliability of the toolkit and proposed processes.

Keywords: *collaborative problem-solving, experiential learning, teaching non-metals.*

Cite This Article: Vu Phuong Lien, Tran Thi Van Trang, and Tran Trung Ninh, "Evaluate Students' Collaborative Problem-Solving Skills Through an Experiential Approach to Teach Non-metals (A Case Study in High School of Education Sciences and Viet Duc High School in Hanoi, Vietnam)." *World Journal of Chemical Education*, vol. 6, no. 4 (2018): 190-199. doi: 10.12691/wjce-6-4-6.

1. Introduction

In this 21st century, nothing can exist on its own. Individuals seek to not only enrich their knowledge but also connect to people around. Thus, cooperating in problem solving is considered one of the most important skills for students. This ability needs to be developed among learners during teaching process in order to enhance desired traits such as diligence, creativity and competitiveness in the present day. Chemistry requires students to apply knowledge from other subjects like Biology, Physics, Mathematics, Geography, etc. Moreover, this subject also relates to many daily phenomena. Therefore, learners have to combine their scientific insights and life experiences in order to figure out different real-life problems about environment, medical, and food safety, etc. As a result, teachers have to give students challenging tasks. The purpose of those tasks is to apply prior knowledge and cooperate with others in learning process. In addition, tools need to be used to evaluate how well students are doing at school. After the evaluation, appropriate strategies and interventions will be carried out to improve students' proficiency in cooperating in problem solving. [1,2]

2. Research Content

2.1. Collaborative Problem-solving Competency

> "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 and pooling their knowledge, skills and efforts to reach that solution". (PISA 2015) [3]

The structure of the Collaborative problem-solving. The structure of the Collaborative problem-solving competency according to PISA provides three core collaborative problems-solving competencies: establishing and maintaining shared understanding, taking appropriate action to solve the problem, establishing and maintaining a team organization. These major competencies are based on a combination of co-operation and problem solving. This competency is also influenced by factors such as mission, team composition, task environment, as well as the general context of the problem solving task. (we can see the factors that affect Collaborative problem-solving competency).

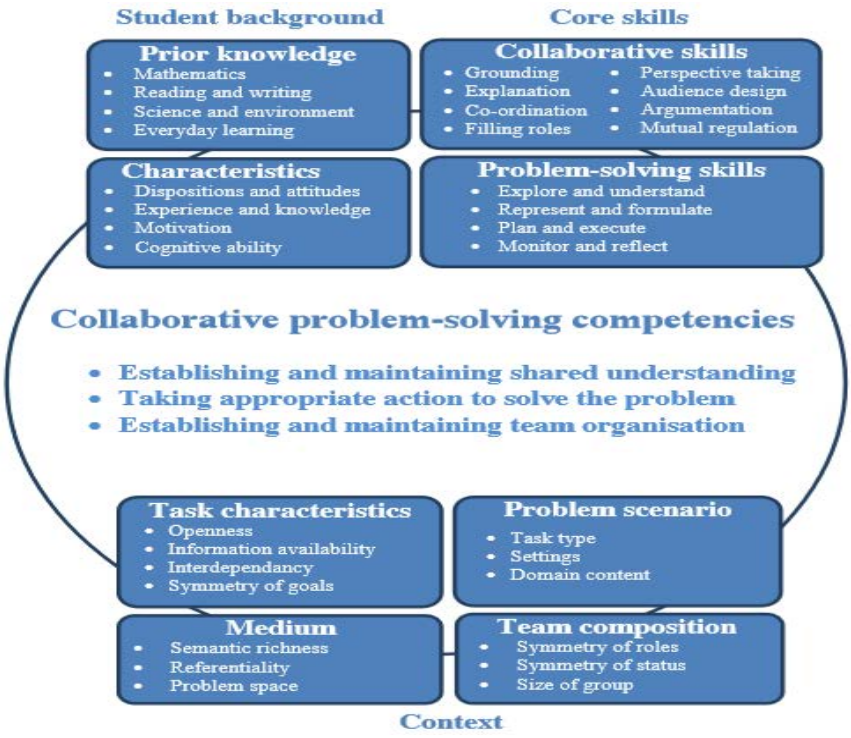


Figure 1. Overview of factors and processes for collaborative problem solving in PISA 2015

Table 1. Matrix of Collaborative Problem Solving skills for PISA 2015

	Establish and maintain shared understanding	Take appropriate action to solve the problem	Maintain team organization
Exploring and understanding	(A1) Discovering perspectives and abilities of team members	(A2) Discovering the type of collaborative interaction to solve the problem, along with goals	(A3) Demonstrating the principles of problem solving
Representing and formulating	(B1) Building a shared representation and negotiating the meaning of the problem	(B2) Identifying and describing tasks to be completed	(B3) Describe roles and team organization
Planning and executing	(C1) Communicating with team members about the actions	(C2) Enacting plans	(C3) Following the guidelines given
Monitoring and reflecting	(D1) Monitoring and repairing the shared understanding	(D2) Monitoring results of actions and evaluating success in solving the problem	(D3) Monitoring, providing feedback and adapting the team organization and roles

Table 2. 36 indicators

(A1) Identify human resources and group-members' abilities	A1.1.Understand group members' advantages and disadvantages	Be unable to understand group members' advantages and disadvantages	Have some understanding but not adequate enough about group members' advantages and disadvantages	Fully understand group members' advantages and disadvantages
	A1.2.Assign appropriate role during group work	Be unable to assign particular role to any group-member	Assign some suitable roles to group members.	Assign roles perfectly to all members
	A1.3Do research and contribute to group	Be unable to share and build resources for the group	Have some but not plenty resources for the group	Have abundant sources to contribute to the group
(A2) Finding types of collaboration to achieve group goal	A2.1.Propose appropriate types of collaboration	Be unable to propose appropriate types of collaboration	Propose simple forms of collaboration	Propose effective and creative forms of collaboration
	A2.2Use different types of teamwork	Use only one type of teamwork	Using a few types of teamwork	Use and combine effectively different types of teamwork
	A2.3.The frequency and quality of team meeting	Have no team meeting or only meet once or twice and thus bring no effect	Frequent team meeting but not really effective	Frequent team meeting and highly effective
(A3) Capable of demonstrating problem solving methods	A3.1.Be able to identify the problem	Be unable to identify problems	Be able to identify several problems but unable to demonstrate them	Be able to identify problems and demonstrate them easily.
	A3.2.Analyze causes	Be unable to find causes	Be able to find causes but unable to analyze	Be able to find and analyze causes
	A3.3.Be able to identify main cause	Be unable to analyze cause	Be able to figure out main cause but demonstrate unconvincingly	Be able to figure out main cause and demonstrate convincingly

(B1) Construct an essay describing the problem and understand the meaning	B1.1Describe the relation between the problem and subject knowledge	Be unable to find the relation	Be able to figure out the relation but demonstrate illogically	Be able to figure out the relation ad demonstrate logically as well as effectively
	B1.2Describe the importance of the problem in real-life	Be unable to describe the importance	Be able to describe ideas but still lacking	Be able to describe ideas effectively
	B1.3Identify the relationship between theory and real-life relating to the problem	Be unable to identify the relationship between theory and real-life relating to the problem	Be able to identify the relationship between theory and real-life relating to the problem	Be able to identify the unified relationship between theory and real-life relating to the problem
(B2) Identify and describe objectives that need to be reached	B2.1Identify and describe the objectives of the subject (a) as well as real-life knowledge needed to solve problem (b)	Be unable to identify both (a) and (b)	Be able to identify either (a) or (b)	Be able to identify and describe both (a) and (b)
	B2.2Identify and describe the objectives of the subject's skills (c) as well as the objectives of problem solving skills (d)	Be unable to identify both (c) and (d)	Be able to identify either (c) or (d)	Be able to identify and describe both (c) and (d)
	B2.3Identify and describe the attitude towards lesson (e) and attitude towards problem solving	Unable to identify either (e) or (f)	Be able to identify either (e) or (f)	Be able to identify and describe both (e) and (f)
(B3) Establish regulations and the group structure	B3.1Elect leader	Have no leader for the group	Have an unsuitable leader	Have a suitable leader who can finish the tasks well for the group
	B3.2 Establish the regulations for the group	Be unable to join the establishment	Participate in establishing group regulations but not enthusiastically	Join the establishment enthusiastically
	B3.3Follow group regulations	Never follow group regulations	Unwillingly follow group regulations	Always follow group regulation willingly
(C1) Communicate with other group members in activities	C1.1Participate in group meeting	Never participate in group meetings	Rarely participate in group meetings	Always participate in group meetings
	C1.2Do research and demonstrate opinions	Never research given tasks	Do research but do not demonstrate opinions	Do research and demonstrate opinions enthusiastically
	C1.3Disscuss in a positive way to figure out the answer	Never join the discussion	Listen but never give feedback to others	Always discuss enthusiastically with others
(C2) Implement the plan to solve problem	C2.1Propose solution	Be unable to propose solution	Propose solution without explanation	Propose solution and give effective explanation
	C2.2Adjust solution based on group members' ideas	Only focus on the differences between ideas	Try to figure out the common feature among solutions	Differentiate between ideas and come to the best solution
	C2.3Consolidate the choice of solution	Have no opinion about the choice of solution	Be unable to consolidate a suitable solution	Be able to consolidate a suitable solution
(C3) Observe groups' regulations	C3.1Record group's process	Never record the group's process	Do not record specifically and logically	Record specifically and logically
	C3.2Give feedback to unenthusiastic members	Never give feedback to unenthusiastic members	Occasionally give feedback on members' work	Always give feedback to unenthusiastic members
	C3.3Adjust groups' regulations in accordance to circumstances	Never figure out the cause to adjust groups' regulations	Figure out the cause but unable to adjust groups' regulations	Figure out cause to adjust groups' regulations
(D1)Correct shared information	D1.1Detect misinformation in general knowledge	Be unable to detect misinformation in general knowledge	Detect little misinformation in general knowledge	Detect all misinformation in general knowledge
	D1.2 Conform, adjust one's behavior in accordance to general knowledge	Keep one's opinions and be unable to acknowledge the accepted information	Agree with group discussion but be unable to adjust one's behavior in accordance to general knowledge	Conform and adjust one's behavior in accordance to general knowledge
	D1.3Modify arguments and solutions based on particular circumstances	Be unable to modify arguments when circumstances change	Make some unsuitable changes	Modify arguments logically based on particular circumstances
(D2) Observation and rating	D2.1Observeproblem solving progress	Have no observation, record of problem solving process	Have some observations but do not record carefully	Observe and record group progress carefully
	D2.2Adjustment	Have no adjustment when solving the problem is impossible	Ineffective adjustment	Adjustment is very effective
	D2.3Rate group's result	Be unable to solve the problem	Ineffective problem solving	Effective problem solving

(D3) Observe, provide feedback and adapt to groups' regulations	D3.1Provide feedback on each group's member	Never provide feedback on group member	Provide feedback but not specific and helpful	Helpful and great impact feedback
	D3.2Share personal opinion to adjust groups' regulations	Never share personal opinion to adjust groups' regulations	Never adjust groups' regulations in accordance to members' opinions	Adjust groups' regulations in accordance to members' opinions
	D3.3Adapt to groups' regulations	Never follow groups' regulations	Adapt to group's regulations but somewhat unwillingly	Completely adapt to groups' regulations
(A1) Identify human resources and group-members' abilities	A1.1.Understand group members' advantages and disadvantages	Be unable to understand group members' advantages and disadvantages	Have some understanding but not adequate enough about group members' advantages and disadvantages	Fully understand group members' advantages and disadvantages
	A1.2.Assign appropriate role during group work	Be unable to assign particular role to any group-member	Assign some suitable roles to group members.	Assign roles perfectly to all members
	A1.3Do research and contribute to group	Be unable to share and build resources for the group	Have some but not plenty resources for the group	Have abundant sources to contribute to the group
(A2) Finding types of collaboration to achieve group goal	A2.1.Propose appropriate types of collaboration	Be unable to propose appropriate types of collaboration	Propose simple forms of collaboration	Propose effective and creative forms of collaboration
	A2.2Use different types of teamwork	Use only one type of teamwork	Using a few types of teamwork	Use and combine effectively different types of teamwork
	A2.3.The frequency and quality of team meeting	Have no team meeting or only meet once or twice and thus bring no effect	Frequent team meeting but not really effective	Frequent team meeting and highly effective
(A3) Capable of demonstrating problem solving methods	A3.1.Be able to identify the problem	Be unable to identify problems	Be able to identify several problems but unable to demonstrate them	Be able to identify problems and demonstrate them easily.
	A3.2.Analyze causes	Be unable to find causes	Be able to find causes but unable to analyze	Be able to find and analyze causes
	A3.3.Be able to identify main cause	Be unable to analyze cause	Be able to figure out main cause but demonstrate unconvincingly	Be able to figure out main cause and demonstrate convincingly
(B1) Construct an essay describing the problem and understand the meaning	B1.1Describe the relation between the problem and subject knowledge	Be unable to find the relation	Be able to figure out the relation but demonstrate illogically	Be able to figure out the relation ad demonstrate logically as well as effectively
	B1.2Describe the importance of the problem in real-life	Be unable to describe the importance	Be able to describe ideas but still lacking	Be able to describe ideas effectively
	B1.3Identify the relationship between theory and real-life relating to the problem	Be unable to identify the relationship between theory and real-life relating to the problem	Be able to identify the relationship between theory and real-life relating to the problem	Be able to identify the unified relationship between theory and real-life relating to the problem
(B2) Identify and describe objectives that need to be reached	B2.1Identify and describe the objectives of the subject (a) as well as real-life knowledge needed to solve problem (b)	Be unable to identify both (a) and (b)	Be able to identify either (a) or (b)	Be able to identify and describe both (a) and (b)
	B2.2Identify and describe the objectives of the subject's skills (c) as well as the objectives of problem solving skills (d)	Be unable to identify both (c) and (d)	Be able to identify either (c) or (d)	Be able to identify and describe both (c) and (d)
	B2.3Identify and describe the attitude towards lesson (e) and attitude towards problem solving	Unable to identify either (e) or (f)	Be able to identify either (e) or (f)	Be able to identify and describe both (e) and (f)
(B3) Establish regulations and the group structure	B3.1Elect leader	Have no leader for the group	Have an unsuitable leader	Have a suitable leader who can finish the tasks well for the group
	B3.2 Establish the regulations for the group	Be unable to join the establishment	Participate in establishing group regulations but not enthusiastically	Join the establishment enthusiastically
	B3.3Follow group regulations	Never follow group regulations	Unwillingly follow group regulations	Always follow group regulation willingly
(C1) Communicate with other group members in activities	C1.1Participate in group meeting	Never participate in group meetings	Rarely participate in group meetings	Always participate in group meetings
	C1.2Do research and demonstrate opinions	Never research given tasks	Do research but do not demonstrate opinions	Do research and demonstrate opinions enthusiastically
	C1.3Disscuss in a positive way to figure out the answer	Never join the discussion	Listen but never give feedback to others	Always discuss enthusiastically with others

(C2) Implement the plan to solve problem	C2.1Propose solution	Be unable to propose solution	Propose solution without explanation	Propose solution and give effective explanation
	C2.2Adjust solution based on group members' ideas	Only focus on the differences between ideas	Try to figure out the common feature among solutions	Differentiate between ideas and come to the best solution
	C2.3Consolidate the choice of solution	Have no opinion about the choice of solution	Be unable to consolidate a suitable solution	Be able to consolidate a suitable solution
(C3) Observe groups' regulations	C3.1Record group's process	Never record the group's process	Do not record specifically and logically	Record specifically and logically
	C3.2Give feedback to unenthusiastic members	Never give feedback to unenthusiastic members	Occasionally give feedback on members' work	Always give feedback to unenthusiastic members
	C3.3Adjust groups' regulations in accordance to circumstances	Never figure out the cause to adjust groups' regulations	Figure out the cause but unable to adjust groups' regulations	Figure out cause to adjust groups' regulations
(D1)Correct shared information	D1.1Detect misinformation in general knowledge	Be unable to detect misinformation in general knowledge	Detect little misinformation in general knowledge	Detect all misinformation in general knowledge
	D1.2 Conform, adjust one's behavior in accordance to general knowledge	Keep one's opinions and be unable to acknowledge the accepted information	Agree with group discussion but be unable to adjust one's behavior in accordance to general knowledge	Conform and adjust one's behavior in accordance to general knowledge
	D1.3Modify arguments and solutions based on particular circumstances	Be unable to modify arguments when circumstances change	Make some unsuitable changes	Modify arguments logically based on particular circumstances
(D2) Observation and rating	D2.1Observeproblem solving progress	Have no observation, record of problem solving process	Have some observations but do not record carefully	Observe and record group progress carefully
	D2.2Adjustment	Have no adjustment when solving the problem is impossible	Ineffective adjustment	Adjustment is very effective
	D2.3Rate group's result	Be unable to solve the problem	Ineffective problem solving	Effective problem solving
(D3) Observe, provide feedback and adapt to groups' regulations	D3.1Provide feedback on each group's member	Never provide feedback on group member	Provide feedback but not specific and helpful	Helpful and great impact feedback
	D3.2Share personal opinion to adjust groups' regulations	Never share personal opinion to adjust groups' regulations	Never adjust groups' regulations in accordance to members' opinions	Adjust groups' regulations in accordance to members' opinions
	D3.3Adapt to groups' regulations	Never follow groups' regulations	Adapt to group's regulations but somewhat unwillingly	Completely adapt to groups' regulations

The three Major competencies of Collaborative problem-solving competency are defined to serve the process of measurement and evaluation. The three core competencies of the Collaborative problem-solving competency are combined with four individual problem solving processes to form a Matrix of collaborative problem-solving skills (Table 1). These evaluation criteria relate to actions, processes, and strategies to determine what it means for students. [3]

Assessing collaborative problem-solving competency. We use several tools to determine student's learning aptitude: framework, rubric, assessment test, self-assessment form and peer-assessment form. Each tool is built based on 36 indicators within 3 levels of rating: elementary, intermediate and advanced following these 12 criteria (Table 2)

According to PISA 2015, the Collaborative problem-solving competency is divided into 4 levels. Each student participating in the assessment will be graded according to the achievement level of each scale. The level of each student will be determined by the average of the Collaborative problem-solving competency, which corresponds to levels 1-4 as described below.

Level 4: - At this level, the students preserves in attempting to complete the task. They explore their task systematically and they appear committed to solving the problem together so they work with their team members with strategies and proactively. Students have an awareness of their performances on the task and monitor the progress towards a solution to the given problem and identify obstacles to be overcome. Students at this level can complete CPS tasks successfully.

Level 3: - At this level Students demonstrates efforts towards solving the problem. The students recognize their team member's roles and the importance of working together. They help each other within the team to understand the task and they share, gather more and connect pieces of information together in order to solve the problem. Students are responsive and report their own activities on the task.

Level 2: - At this Level, students can contribute to a collaborative effort within a problem space of medium difficulty. They can solve a problem by communicating with team members about the actions to be performed. They can help the team establish a shared understanding of the steps required to solve a problem, however students

only use the resources that are immediately available even though they can request additional information which is needed to solve the problem.

Level 1: - At this level 1, students can complete tasks with low problem complexity and limited collaboration complexity. The students commence the task independently focusing only on the information provided. At this level, students can confirm actions or proposals made by others. With support from team members, and working within a simple problem space, these students can contribute to a problem solution.

2.2. Experiential Learning

Experimental learning involves activities that enable learners to observe, discuss, analyze, and reflect to make decisions to solve problems.

The process of experimental learning includes: teacher's activities (control, guidance, orientation) with the experiential learning activities (based on the specific knowledge and experience) of the learner to confirm and systematize the knowledge, skills to meet the teaching objectives. In experiential learning, the teaching activity of teachers is mainly derived from the individual knowledge, the specific experience of the learners. This is analyzed and synthesized by the teachers, and the training objectives are to present the contents and tasks as well as the solutions for each group and each subject so that each student feels that their knowledge and experience are shared and they are contributing to the content of the lesson. So whenever possible, teachers have to create situations and learning opportunities for learners to find out the answers and solve problems. [2]

Based on the study of David Kolb's experiential theory, the process of experiential learning can be described in Figure 2 (Kolb, 1984).

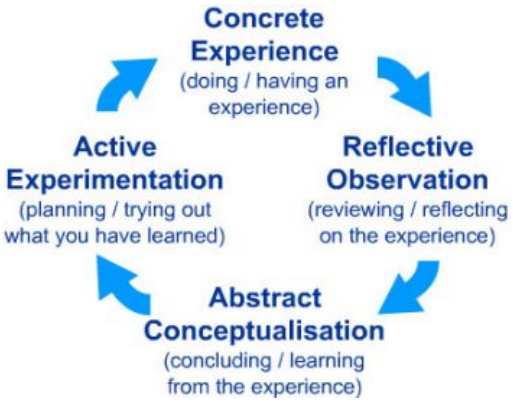


Figure 2. Experiential learning cycle

- Concrete Experience - (a new experience or situation is encountered, or a reinterpretation of existing experience).
- Reflective Observation of the new experience. (of particular importance are any inconsistencies between experience and understanding).
- Abstract Conceptualization (reflection gives rise to a new idea, or a modification of an existing abstract concept).
- Active Experimentation (the learner applies them to the world around them to see what results).

Procedure. From the proposed learning process, we developed a teaching plan for 2 topics, which include activities described in detail in four steps of the process:

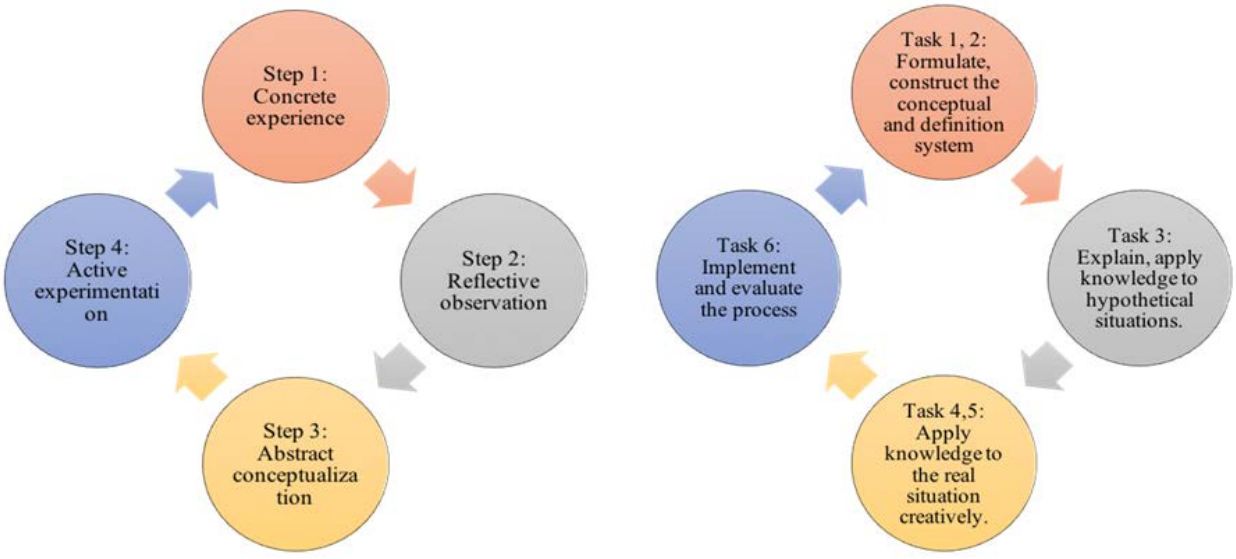


Figure 3. The correspondence between the steps of the experiential process and the experiential learning plan

Step 1 corresponds to task 1 & 2: formulate, construct the conceptual and definition system. Students read books, textbooks, magazines, articles on related topics, attend lectures, watch some videos on the internet on the topics they are learning from; from then on, they will build and form their own concepts and definitions of structural formulas and physical properties.

Step 2 corresponds to task 3: explain and apply knowledge to hypothetical situations. After forming the definition and concept in step 1, at this stage the learner needs to reflect and ask themselves self-answering questions about issues related to the topic. Make sense of hypothetical situations in the topic.

Step 3 corresponds to task 4 & 5: apply knowledge to the real situation creatively. After observing and thinking about the logic reflection in step 3, learners concretize that knowledge by explaining the phenomena in daily life in a flexible and creative way based on chemical properties,

structural formulas of substances, compounds. Through the process of applying the knowledge into the phenomena in daily life, those experiences become the knowledge of the learner's.

Step 4 corresponds to task 6: It is the step of doing all the work to solve problems related to the topic through concepts, definitions, structural formulas, physical properties, chemical properties. Then it is the process of evaluating the implementation process, from which to detect, correct and refine the shortcomings.

2.3. Build Documents for both Teachers and Students

Students' document will include 5 to 6 specific study missions. The tasks will help enhance students' cognition in accordance to Bloom scale. Each of them includes objectives and procedure. Objectives will help students identify the mission, from which, learners will be able to evaluate whether they have completed the task or not. Below the objectives is procedure of many activities for students to interact. The interaction on given document and the experience in final task (task 4,5) will help students answer the big question of the topic. The table below shows the correlation between teachers and students' documents.

2.4. Current Study

- Experiential objects: Class 10A5 in high school education of science, 10A2 in Viet Duc high school

- Experiential lesson plan:

Topic 1: Compounds of sulfur in daily life

Topic 2: Oxygen, Ozone and their applications in daily life

Develop assessment toolkit corresponding to 2 topics

To assess the achievement of the objectives of the lesson, we used four different types of assessment: observation form, peer assessment form, test and report of group product Selection of indicators follows the following principles:

- Observation form: The indicators included in the observation form are often easy to expose and can be assessed through group assessments as well as the teacher's knowledge for assessment. This will make it easier for teachers to observe large number of students in the classroom.

- Peer assessment form: Selection of personal indicators, not highly knowledgeable, are usually indicators of the consciousness, the team members can easily measure their own indicators, as well as members of the group.

- Test and group product: Measure indicators related to knowledge, attitude, skills, attitude of the subject as well as the matter. The two tools will measure the same indicators, but the test will give you an estimation of the level of individual achievement rather than just group assessment.

Below, we propose a CPS matrix assessment tool based on four criteria and 36 indicators.

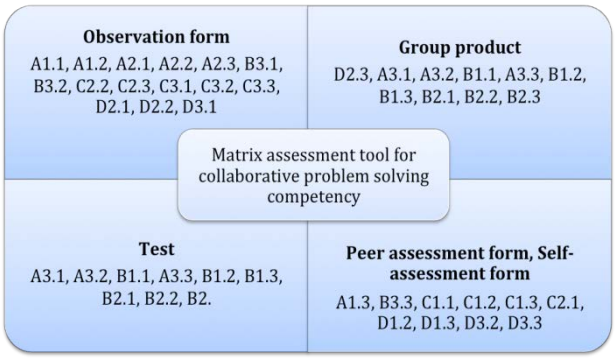


Figure 4. Matrix assessment tool for collaborative problem solving competency

Teaching process

Lesson 1: Teacher introduces the topic, divides students into 3 groups (and assigns tasks for students to report in Lesson 2) (15 minutes)

- Students complete the task 1 + 2 in the student materials in pairs (2 students sitting next to each other is a pair). (15 minutes)

- Teacher gives a few pairs of students an opportunity to present and agree on the correct answers. (15 minutes)

Lesson 2: Resolve tasks 3,4 and 5

- Students discuss and complete tasks at home

- Groups report group product. Each group shall present in (10 minutes)

- Teacher asks students to follow the group presentation, ask questions, make comments, and then the teacher will adjust (15 minutes)

Table 3. The correlation between teachers and students' documents

Tasks	Teachers documents	Students documents
1, 2: Create definition and concept system	- Method: conversation, presentation combined with visual aids, games.	- Comprehension level: memorizing, understanding - Exercise: fill in the blank, matching
3: Apply studies in hypothetical situation	- Task: Give exercises and instruct students then help them correct the mistakes - Method: work as individuals or in group, conversation, presentation	- Task: do given exercises to reinforce skills - Comprehension level: understanding, applying
4,5: Apply studies effectively in real-life situations	- Task: Provide research, experience and creativity paths. Guide students throughout their creative experience - Method: group teaching in club, experiment, etc.	- Task: perform experiment themselves to reinforce studies, creative is allowed visually (presentation) or in content. - Comprehension level: applying, analyzing, creativity
6: Evaluation	- Task: Provide self-assessment form; evaluate student's study performance through a particular study activity given by the teacher. Use rubrics to evaluate group work, Coggle Diagram, etc. - Method: do test in individually and product assessment after each topic	- Task: Participate in hypothetical situation given by teacher to be evaluated - Comprehension level: summarizing, evaluating.

Table 4. Student materials, teacher materials corresponding to 2 topics

Purpose of the task	Specific task	Student materials	Teacher's Lesson plan
Topic 1: Compounds of sulfur in daily life			
Task 1, 2: To formulate, construct the conceptual and definition system	Task 1: Understand the molecular structure of SO2, SO3, sulfuric acid, sulfate salt and bisulfate salt.	- Structural formula images and description tables (left unfilled) of SO_2, SO_3, sulfuric acid, sulfate salt and bisulfate salt	Ask students to look at the structural formula images and fill in the table
	Task 2: Understand the physical properties of sulfur compounds and explain some phenomena in daily life based on their physical properties.	- Pieces of information about SO_2, SO_3, H_2S, H_2SO_4, … - Table of information (left unfilled) on physical properties, phenomena in daily life of SO_2, SO_3, H_2S, H_2SO_4.	Ask students to read the pieces of information and match them with each substance in the table. Then from the piece of information, infer and fill in the empty sections in the table.
Task 3, 4, 5: To explain, apply knowledge to hypothetical situations. To apply knowledge, apply the practice to the real situation creatively.	Task 3: (Experiment 1) Study the chemical properties and effects of hydrogen sulfide gas on the human body.	- Table of chemical properties of hydrogen sulfide (left unfilled). - Table of constructing experimental systems to demonstrate the properties of hydrogen sulfide (left unfilled).	- Ask students to predict the chemical properties of hydrogen sulfide. - Ask students to present, the other students listen, respond and complete the table. - Ask students to construct a test that demonstrates the chemical properties of hydrogen sulfide (perform the experiment, complete the table).
	Task 4: Experience 2: Study the chemical properties of sulfur dioxide and explain the acid rain phenomenon and the effects of acid rain on daily life	- Table of information on the chemical properties of sulfur dioxide (left unfilled) - Pieces of information about acid rain - Questions related to sulfur dioxide and acid rain	- Ask students to predict the chemical properties of sulfur dioxide. - Ask students to present, the other students listen, respond and complete the table.
	Task 5: Experience 3: Study the chemical properties of carbonate and hydrogen carbonate salts	- Table of information on the chemical properties of sulfuric acid (left unfilled) The table compares the chemical properties of diluted sulfuric acid and concentrated sulfuric acid. - Applications of sulfate salts, and equations for the preparation of sulfate salts (left unfilled)	- Ask students to predict the chemical properties of diluted sulfuric acid and concentrated sulfuric acid - Ask students to present, the other students listen, respond and complete the table.
Task 6: To Evaluate and summarize	Task 6: Evaluation and summary	- Checklist, self-assessment form, observation form ...	- Ask students to complete the self-assessment form (individual assessment) and group assessment form provided by the teacher. - Ask students to summarize and systemize the entire knowledge of the topic, teacher will comment on the summary. - Ask students to complete the content of the student materials
Topic 2: Oxygen, Ozone and their applications in daily life			
Task 1, 2: To formulate, construct the conceptual and definition system	Task 1: Understand the molecular structure of O_2 and O_3	- Structural formula images of O_2 and O_3. - Description table (left unfilled)	Ask students to look at structural formula images of O_2 and O_3 and complete the description.
	Task 2: Understand the physical properties of O_2, O_3 and some phenomena in daily life based on their physical properties.	- Pieces of information about O_2, O_3. - Question explaining the phenomena on the pieces of information	Ask students to read the pieces of information and answer questions related to the pieces of information.
Task 3, 4, 5: To explain, apply knowledge to hypothetical situations. To apply knowledge, apply the practice to the real situation creatively.	Task 3: (Experience 1) Study the chemical properties and application of O_2 to daily life.	- Table of chemical properties and corresponding application of O_2 - Table of constructing experimental systems to demonstrate the properties of O_2	- Ask students to predict the chemical properties of O_2 and explain the application of O_2 - Ask students to present, the other students listen, respond and complete the table. - Ask students to demonstrate the chemical properties of O_2
	Task 4: Experience 2: Study the chemical properties of O_3 and explain the application of O_3 in different fields	- Table of information on the chemical properties of O_3 - Pieces of information about the application of O_3 - Questions to demonstrate the application of O_3 from its properties	- Ask students to predict the chemical properties of O_3 and to demonstrate the relationship between chemical properties and the application of O_3. - Ask students to present, the other students listen, respond and complete the table.
	Task 5: Experience 3: Preparation of O_2 and O_3	- Pieces of information about the formation of O_2 and O_3 in the air. - Questions related to the pieces of information. - Table about performing the experiment on the preparation of O_2 and O_3	- Ask students to discuss and complete the information table. - Ask students to cooperate to perform the experiment and then make a presentation, the other students listen, respond and complete the table.
Task 6: To evaluate and summarize	Task 6: Evaluation and summary	- Checklist, self-assessment form, observation form ...	- Ask students to complete the self-assessment form (individual assessment) and group assessment form provided by the teacher. - Ask students to summarize and systemize the entire knowledge of the topic, teacher will comment on the summary. - Ask students to complete the content of the student materials

Lesson 3: Assessment

- Students take a quiz (15 minutes)
- Students discuss with the team members to complete the observation form, peer assessment form.
- Teacher collects the forms and receives feedbacks from the students, agreeing the assessment results.

Data analysis

Reliability of the assessment tools

We measured the reliability of each assessment tool, obtaining the result that Cronbach's Alpha reliability of tools with values ranging from 0.692 to 0.855 are usable (Nunally, 1978; Peterson, 1994; Slater, 1995), as follows:

Thus, it is entirely possible to use this assessment tool to carry out an assessment of the student's collaborative problem-solving competency through the process of teaching chemistry in the form of experiential learning.

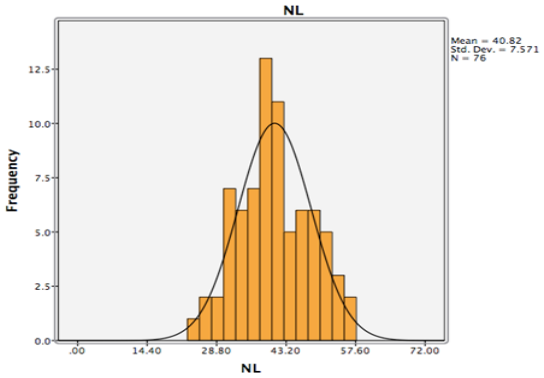
Suggestion for an assessment scale for Collaborative problem-solving competency and Major competencies

Based on the results of the reliability calculation of the toolkit and the competency structure, we conducted a statistical analysis describing the second result to be able to propose an assessment scale for Collaborative problem solving competency.

Statistics

		NL	NL1	NL2	NL3
N	Valid	76	76	76	76
	Missing	0	0	0	0
Mean		40.8158	13.4868	13.2961	14.5658
Median		40.2500	13.0000	13.0000	14.5000
Mode		40.00[a]	12.00	13.00	14.00[a]
Std. Deviation		7.57093	2.72883	3.06178	2.98367
Minimum		24.00	7.50	7.00	7.50
Maximum		57.00	20.00	20.00	21.00
Percentiles	15.14	32.3289	11.0000	9.5000	11.5000
	50	40.2500	13.0000	13.0000	14.5000
	84.86	49.6711	17.0000	17.0000	17.6711

a. Multiple modes exist. The smallest value is shown



Collaborative problem solving competency

The results of the above statistics show that the mean, median, and mode scores of the measurement results of collaborative problem-solving competency and component capabilities are close to the standard distribution, therefore; the standard distribution theory can be used to identify and propose an assessment scale for collaborative problem-solving competency in this study as follows:

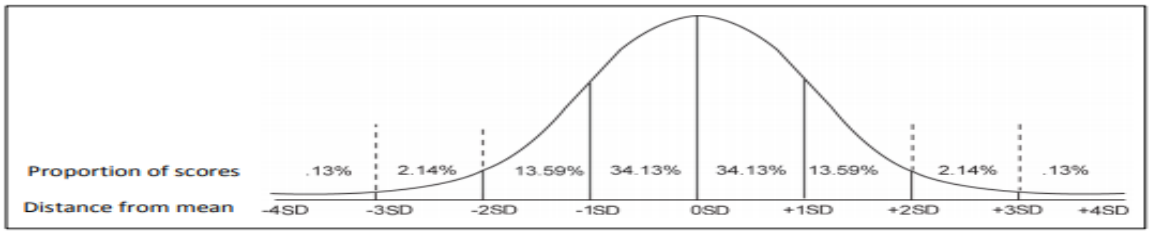


Table 5. Describe the levels of students' Collaborative problem-solving competency formed in the process of interdisciplinary integration in the teaching of natural science

Level (Score range)	Level 1 (24.0-32.32)	Level 2 (32.5-40.25)	Level 3 (40.5-49.67)	Level 4 (50.0-57.0)
Describe the levels of Collaborative problem solving competency	Students are able to complete tasks with low problem complexity and limited collaboration complexity	Students can contribute to collaborative efforts in a problematic space at moderately difficult levels. They may be involved in problem solving by contacting the team members about the actions taken.	Students can complete tasks with high problem complexity or high collaboration complexity. They can perform tasks that require the integration of multiple pieces of information, usually in complex and dynamic problem spaces.	Students can successfully complete complex problem solving with high collaboration complexity. They can solve problems in complex problem spaces with many difficulties, gaining knowledge through problem solving.

Table 6. Describe the levels of students' major competency Establish and maintain shared understanding formed in the process of interdisciplinary integration in the teaching of natural science

Level (Score range)	Level 1 (7.5-11.0)	Level 2 (11.25-13.0)	Level 3 (13.25-17.0)	Level 4 (17.25-20.0)
Describe the levels of major competency Establish and maintain shared understanding	Engage in the process of establishing a common understanding of the relationship between theory and practice. Participation is not active, there is no cognitive and behavioral adjustment to be consistent with other ideas, methods to solve problems of team members.	Engage and share in the process of establishing a common understanding of the relationship between theory and practice. Initially, there is cognitive and behavioral self-adjustment to be consistent with other ideas, methods to solve problems of team members.	Engage and share in the process of establishing a common understanding of the relationship between theory and practice. Resolve some basic contradictions in the process by adjusting and self-adjusting to maintain a common understanding among team members.	Engage, communicate and share well in the process of establishing a common understanding of the relationship between theory and practice. Resolve contradictions in the process of maintaining common understanding by understanding strengths of each individual.

Table 7. Describe the levels of students' major competency Take appropriate action to solve the problem formed in the process of interdisciplinary integration in the teaching of natural science

Level (Score range)	Level 1 (7.0-9.5)	Level 2 (9.75-13.0)	Level 3 (13.25-17.0)	Level 4 (17.25-20.0)
Describe the levels of major competency Take appropriate action to solve the problem	Identify appropriate cooperation on the basis of common understanding. Do not clearly identify objectives and develop plans with supervision.	Identify and organize appropriate cooperation on the basis of common understanding. Determine the objectives to be formed. However, the proposed solution / plan does not fit the objectives	Identify and organize appropriate cooperation on the basis of common understanding. Initially, choose the solution, the plan to solve the problem on the basis of unified objectives to be formed.	Identify and organize appropriate cooperation on the basis of common understanding. Resolve the problem on the basis of objective alignment, implementation plan with process monitoring.

Table 8. Describe the levels of students' major competency Maintain team organization formed in the process of interdisciplinary integration in the teaching of natural science

Level (Score range)	Level 1 (7.5-11.5)	Level 2 (11.75-14.5)	Level 3 (14.75-17.67)	Level 4 (17.75-21.0)
Describe the levels of major competency Maintain team organization	Set out the principle of problem solving, and the group's principles but unclear. The process is still confusing.	Set out the principle of problem solving, and the group's principles During operation, some principles are not guaranteed.	Set out the principle of problem solving, and the group's principles Follow the principles of collaborative problem solving with the supervision of the whole team.	Set out the principle of problem solving, and the group's principles Implement flexible principles of collaborative problem solving with the supervision of the whole team.

From the above statistics, the average student's collaborative problem solving competency is 40.8/ 72 points. Students mostly score 2.3 points; demonstrating that students can contribute to collaborative efforts in a problem space at moderately difficult levels or that some students can complete tasks with high complexity or complex collaborative needs.

GPA of major competency 1 (13.48/24.0) of students achieves level 3; major competency 2 (13.29/24.0) and major competency 3 (14.49/24.0) of students achieves level 3. This shows that students continue to maintain their good engagement, communication and sharing in the process of establishing a common understanding of the relationship between theory and practice, which resolves contradictions in the process of maintaining common understanding by understanding strengths of each individual. In addition, students need to practice the ability to compare and evaluate the advantages and disadvantages of problem solving methods to be able to provide the most optimal, feasible solution, consistent with the goal to be formed. At the same time, students need to improve the ability to evaluate the strengths of their arguments and those of other members, thereby adjusting their views and behaviors to suit the common knowledge to resolve disputes in the process of cooperation.

3. Conclusion

Develop and experiment two topics of teaching chemistry in the form of experiential learning with two sets of materials for students and teachers. Through the pedagogical experience process, the reliability of the assessment tool has been verified to an acceptable level. Most students have developed moderate and good Collaborative problem solving competency, and they can contribute and complete tasks with moderate and high complexity.

Two topics of teaching chemistry in the form of experiential learning with two sets of materials for students and teachers are developed and experimented. Through the pedagogical experience process, the reliability of the assessment tool has been verified to an acceptable level. Most students have developed moderate and good Collaborative problem solving competency, and can contribute and complete tasks with moderate and high complexity.

Collaborative problem-solving competency of high school students can be assessed through the teaching of chemistry from the experiential approach. However, in addition to reviewing and re-expressing some indicators, teachers need to have better supervision and control in the process of team work of students as planned. Applying the experiential education process in a broader chemistry teaching approach can help students develop Collaborative problem solving competency, while continuing to standardize toolkits and compare collaborative problem-solving competency among students in different regions.

References

[1] Le Thai Hung, Vu Phuong Lien, Nguyen Thi Phuong Vy, Assessing Collaborative Problem Solving Competency Through Integrated Theme Based Teaching Chemistry, Proceedings of the International Conference on Research of Educational Administration and Management (ICREAM 2017), October 17, 2017, Bandung, Indonesia, Taylor & Francis Group, UK.

[2] Vu Phuong Lien, Ngo Nam Sinh, Establish the Collaborative problem-solving competency of students through teaching chemistry in the form of experiential education, Journal of Educational Science, 146, 11/2017.

[3] PISA 2015, Draft Collaborative Problem Solving framework, OECD Program for International Student Assessment 2015.

[4] Grinffin, E. C. Assessment of Collaborative Problem Solving, 2015

[5] NESTA, Solved! Making the case for collaborative problem solving, 2017.

[6] Patrick Griffin, Esther Care, developing learners' collaborative problem solving skills, 2015.

[7] PISA 2018, Draft framework.

[8] Rod Ellis, The Methodology of Task-based teaching.

[9] Worf, A, Competence – Based Assessment, 1995.

[10] Tran Trung Ninh, Vu Phuong Lien, Collaborative problem-solving competency of students through teaching chemistry in high school, Journal of Educational Sciences, Vol. 2, 02/2018.