

Assessment of Problem Solving Ability and Creativity in Chemistry Teaching at Secondary Schools in Binh Dinh, Vietnam

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Abstract Chemistry plays an important role at the secondary school in developing common abilities and professional abilities, including problem solving competency and creativity. This is one of the core competencies that need to be set up and developed for students to meet the requirements of general education's renovation. The assessment of the learner's ability to solve problems and creativity has many meanings in the educational process. This article presents a process for assessing problem solving competency and creativity in teaching chemistry at secondary schools in Binh Dinh Province, Vietnam.

Keywords: *assessment, problem solving competency and creativity, chemistry, secondary school*

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1. Introduction

Problem-solving competency and creativity is one of the important abilities that needs forming and developing for secondary students. This is one of the abilities that helps students succeed in learning and in real life. Assessing learner's abilities is a complex activity because they are hidden variables, the sum of many factors. There have been a number of studies on problem-solving competency and creativity in chemistry teaching published by Cao Thi Thang, Pham Thi Bich Dao [1,2,3,4], Wüstenberg, Greiff [5], & Funke [6], Novick, L. R., & Bassok [7], Jonassen [8]... In these studies problem-solving competency and creativity competency were studied separately in the direction to look for measures to develop it. The author Nguyen Thi Lan Huong [2,9], Ronny Scherer, Rüdiger Tienmann [10,11] has also done many studies on the assessment of the learner's competencies, proposed structures and standards for assessing problem-solving competency in the general education curriculum. However, there have been no studies presenting the process of evaluating problem-solving competency and creativity in teaching chemistry in secondary schools. The research and development of problem-solving and creativity assessment process bears significant theoretical and practical implications. The scale can assist in measuring and evaluating problem-solving competency and creativity, while also providing the right orientations in fostering and developing this competency for secondary students.

2. Content

2.1. Theoretical bases of ability assessment

The ability assessment is based on the following three basic theories [9]:

- Lev Vygotsky's Zone of proximal Development Theory (1896-1934);
- Robert Glaser's Theory of Development Path (1921-2012);
- Rasch's Item Response Theory (1901-1980).

From these theories emerged the idea of "building an ability framework for use in both the assessment and the process of education and training". This idea can be implemented by two approaches:

- Performance Based Competency Standards are often used where the national training framework has been enacted, for example, in Australia, New Zealand, and South Africa...

- Competency Moderation Approach. The main function of the competency moderation is to ensure that different applications of the standard are maintained within an acceptable limit.

The course based competency standards should take advantage of both approaches. The competency standards are described in detail through course competency structure and competency development path. To do so, it is necessary to carry out the following five major activities:

- Define the concept of competency
- Build competency structure including component competencies & behavioral indices

- Describe the scope of each component through the quality criteria
- Set up the competency development path
- Inspecting the development path through student samples and tools; modify and improve the competency development path and competency standards.

Moderation will be used in all the above activities.

2.2. Process of Assessing Problem Solving Competency and Creativity

Using the above-mentioned theoretical basis, we propose a 7-step assessment process for problem solving competency and creativity as presented in Table 1.

Table 1. Steps to assess problem solving competency and creativity

Step	Content
1	Study documents that define the concept of problem solving competency and creativity.
2	Define problem solving competency and creativity structure including component competencies and behavioral indices.
3	Describe the scope of each component of problem solving competency and creativity through quality standards.
4	Establish the development path and standards of problem solving competency and creativity.
5	Identify methods and develop tools for assessing of problem solving competency and creativity.
6	Inspect the development path through student samples and tools.
7	Edit, improve the competency development path and competency standards.

2.2.1. The Concept of Problem Solving Competency and Creativity

There are two approaches to of problem solving competency and creativity, a traditional approach to the problem solving competency and creativity with the process of problem solving competency, and a modern approach with information processing [9,10,11]. The 2015 Program of International Student Assessment (PISA) combined problem solving competency and collaborative competency [12,13]. The 2017 global General Education Program of Vietnam has combined problem solving competency and creativity competency into creative problem solving.

For students, creative problem solving in learning is applying learning problem solving to find new ones at a

certain level. In order to have problem solving competency and creativity, the subject must be in a problematic situation, seeking to resolve a cognitive or behavioral conflict and, as a result, develop a new resolution.

2.2.2. The Structure of Problem Solving Competency and Creativity

From their researches with reference to experiences of developed countries, in comparison with the education requirements and conditions in the country in the coming years, Vietnamese education scientists have proposed the orientation of the output quality and competency standards of the general education program, in which the specific manifestations of problem solving competency and creativity in secondary schools [14] (Table 2).

Table 2. Problem solving competency and creativity structure of secondary school students

Component competencies	Behaviors
1. Recognize new ideas.	Identify and clarify new information and ideas; analyze, summarize relevant information from a variety of sources.
2. Detect and clarify problems	Analyze situations in learning; Detect and identify problematic situations in learning.
3. Form and implement new ideas	Detect new and positive elements in other people's opinions; form ideas based on given sources of information; suggest improvement solutions or replace outdated solutions; compare and comment on proposed solutions.
4. Propose and select solutions.	Identify and understand related information; propose solutions to problem solving.
5. Implement and assess solutions to problem-solving	Implement solutions to problem solving and recognize whether the solutions are appropriate or not.
6. Independent thinking	Ask different questions about a thing, a phenomenon; listen carefully to perceive information or ideas with consideration; Pay attention to evidence when considering and evaluating things or phenomena, assessing problems and situations under different viewpoints.

2.2.3. Establishing Quality Criteria for Behaviors of Problem Solving Competency And Creativity

From experts' reviews and modifications, we propose to describe the quality criteria for behavior of problem solving competency and creativity as showed in Table 3.

Table 3. Description behaviors and quality criteria of problem solving competency and creativity

Component competencies	Behaviors	Quality criteria			
		Level 1	Level 2	Level 3	Level 4
1. Recognize new ideas.	1. Identify and clarify new information and ideas. First signals emerge	The new information and ideas as well as the first signals are unclear.	Identify and clarify some new information, ideas and first signals.	Identify and clarify information, new ideas or first signals, but not complete.	Determine clearly the new information, ideas or first signals in full details.
2. Detect and clarify problems	2. Detect and raise problematic situations in learning and in real life, suggest questions for research.	Not yet detect and raise problematic situations in learning and in real life.	Detect and raise problematic situations in learning and in real life, but not yet suggest questions for research.	Detect and raise adequate problematic situations in learning and in real life, suggest questions for research.	Detect and raise adequately and in details problematic situations in learning and in real life, suggest questions for research in details

Component competencies	Behaviors	Quality criteria			
		Level 1	Level 2	Level 3	Level 4
3. Form and implement new ideas	3. Collect information related to the problem and form new ideas.	No new ideas are formed.	Form new ideas, though insufficient and incoherent, based on suggested sources of information.	Form adequate ideas based on given information sources.	Gather information related to the problem, form, connect, and share new ideas with friends
	4. Propose solutions to improve or replace solutions that are no longer suitable.	Cannot propose solutions to improve or replace solutions that are no longer suitable.	Propose some solutions to improve or replace the solutions that are no longer suitable, but not reasonable.	Propose some reasonable solutions to improve or replace the solutions that are no longer suitable.	Propose adequate and reasonable solutions to improve or replace the solutions that are no longer suitable.
4. Propose and select solutions	5. Able to propose problem-solving solutions.	Unable to propose problem-solving solutions.	Propose some problem-solving solutions, but not reasonable.	Propose some reasonable problem-solving solutions	Propose adequate and reasonable P-S solutions
	6. Able to compare and comment on proposed solutions.	Unable to compare proposed solutions.	Able to compare proposed solutions.	Able to compare and comment on proposed solutions.	Able to assess the value of the proposed solutions.
5. Implement and assess problem-solving solutions	7. Implement problem-solving solutions.	Unable to implement problem-solving solutions	Do poor implementation of problem-solving solutions.	Well implement problem-solving solutions.	Very well implement problem-solving solutions.
	8. Identify the suitability or unsuitability of implemented solutions.	Unable to identify the suitability or unsuitability of implemented solutions.	Able to identify the suitability or unsuitability of implemented solutions, but not completely.	Able to identify the suitability or unsuitability of implemented solutions.	Able to evaluate implemented solutions and draw adequate conclusions.
6. Independent thinking	9. Apply solutions to new situations.	Unable to apply solutions to new situations.	Apply unsuitably solutions to new situations.	Apply solutions to new situations suitably.	Apply solutions to new situations suitably and creatively.
	10. Receive and evaluate issues in different perspectives	Cannot yet perceive and evaluate the problem.	Perceiving and evaluating the problems is somewhat one-sided.	Perceive and evaluate the problem adequately.	Perceive and evaluate problems with flexibility, creativity under different perspectives.

2.2.4. Building the Development Path and Problem Solving and Creativity Standards

The purpose of developing ability standards is to determine the competency levels needed at the end of each education stage. These levels are often described as a competency development path [9].

2.2.4.1. Development path of problem solving ability and creativity

Based on the structure (including 6 components and 10 behaviors) and the quality criteria of problem solving competency and creativity, we have developed a development path of problem solving competency and creativity for secondary schools. Accordingly, problem solving competency and creativity of secondary school students can develop through 6 levels from low to high as described in Figure 1.

6. Independent thinking
5. Implement and evaluate the solution problem solving competency and creativity
4. Proposing and selecting solutions
3. Form and implement new ideas
2. Find and clarify the problem
1. Get out new ideas.



Figure 1. Competency development path for problem solving competency and creativity

2.2.4.2. Standard capacity for problem solving and creativity

Based on the developmental approach to problem solving competency and creativity and the results of the small sample of students, we outlined the problem solving and creative competence standard in teaching chemistry in secondary school as described in Table 4.

Table 4. Standard capacity for problem solving and creativity

Levels	Behaviors
Level 6	Apply the solution to the new context. Perceive and evaluate the problem under different perspectives.
Level 5	Implement problem-solving solutions. Identify the suitability or unsuitability of performed solutions.
Level 4	Propose solutions. Compare and comment on proposed solutions.
Level 3	Gather information related to the problem and form new ideas. Suggest solutions to improve or replace inappropriate solutions.
Level 2	Detect and raise problematic situations in study and in real life, propose questions for research.
Level 1	Identify and clarify new information or ideas. Displays first signs.

2.2.5. Methods and Tools for Assessing Problem Solving Competency and Creativity

The assessment of competency in general, and problem solving competency and creativity in particular, is conducted both in the learning process and at the end of the study topic [9]. The assessment should be conducted with a variety of methods such as tests, essay writing,

practice, situational exercises, observation... In addition, it is necessary to create opportunities for all students to actively evaluate themselves and their peers.

Checklists were used to observe behaviors and situational assessment methods to design a toolkit for assessing students' problem solving competency and creativity in Chemistry teaching in secondary schools:

2.2.5.1. Use the checklist to examine the behaviors

The specific behaviors of each component of the problem solving competency and creativity are presented in a list, which can help teachers to observe student's learning and students to assert to what extent they have performed the behaviors.

2.2.5.2. Evaluate situations

Situation assessment is the assessment of the student's performance in a situation involving actual work experience. The following sample form can be used for the article

"Acetic acid" - grade 9 at secondary school.

15-MINUTE TEST

School Class Full name

Experiments with acetic acid gives unpleasant smells.

1. The problem raised here is:

.....

2. The solutions are:

a.

b.

c.

d.

3. Assessment of solutions:

	<i>Solution Strengths</i>	<i>Weaknesses</i>
	<i>Solutions</i>	<i>Strong points</i>
a.		<i>Weak points</i>
b.		
c.		
d.		

4. The optimal solution is:

Table 5. The checklist examines students' problem solving competency and creativity

School: Name of teacher:

Class: Name of student:

Behaviors	Quality criteria			
	Level 1(1 point)	Level 2(2 points)	Level 3 (3 points)	Level 4 (4 points)
1. Identify and clarify new information and ideas.				
2. Identify and raise problematic situations in study and in real life, propose research questions.				
3. Collect information related to the problem and form new ideas.				
4. Suggest solutions to improve or replace inappropriate solutions.				
5. Propose solutions to solve the problem.				
6. Compare and comment on proposed solutions.				
7. Implement problem solving solutions.				
8. Identify the suitability or unsuitability of performed solutions.				
9. Apply solutions into new situations.				
10. Perceive and evaluate problems in different perspectives.				

Table 6. Rubric of ability to solve problems and creativity of students

School: Class:

Name of student:

Behaviors	Quality criteria			
	Level 1(1 point)	Level 2 (2 points)	Level 3 (3 points)	Level 4 (4 points)
1. Identify and clarify new information and ideas.				
2. Identify and raise problematic situations in study and in real life, propose research questions.				
3. Collect information related to the problem and form new ideas.				
4. Suggest solutions to improve or replace inappropriate solutions.				
5. Propose solutions to solve the problem.				
6. Compare and comment on proposed solutions.				
7. Implement problem-solving solutions.				
8. Identify the suitability or unsuitability of performed solutions.				
9. Apply solutions into new situations.				
10. Perceive and evaluate problems in different perspectives.				

2.2.6. Verify the Competency Development Path through Student Representative Samples and Tools

We conducted the pedagogic experiment on 39 students of class 9A1 of Ngo May secondary school in Binh Dinh province, school year 2017-2018, to assess their problem solving competency and creativity

through the Observatory checklists, self-evaluation tests, situational evaluation tests, experimental classes taught with the hands-on method. Here are some sample result reports:

2.2.6.1. Explain, report the problem solving competency and creativity of individuals

Table 7. Explanation, report on the problem solving competency and creativity of individuals

School:Class: Full name:

Levels	Behaviors	Points
Level 6	Apply the solution to the new context. Perceive and evaluate the problem under different perspectives.	86 - 100
Level 5	Implement problem-solving solutions. Identify the suitability or unsuitability of performed solutions.	71 - 85
Level 4	Propose solutions. Compare and comment on proposed solutions.	51 - 70
Level 3	Gather information related to the problem and form new ideas. Suggest solutions to improve or replace inappropriate solutions.	31 - 50
Level 2	Detect and raise problematic situations in study and in real life, propose questions for research.	16 - 30
Level 1	Identify and clarify new information or ideas. Displays first signs.	1 - 15

2.2.6.2. Explain, report on the problem solving competency and creativity development of the class

Table 8. Explanation, report on the problem solving competency and creativity development of the class

School: Ngo May Secondary School Class: 9A1 Group: 2

No.	Student's full name	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6
1	Nguyễn Thị Phương Thảo	██████████	██████████	██████████			
2	Ngô Gia Hán	██████████	██████████	██████████			
3	Nguyễn Khánh Huyền	██████████	██████████	██████████			
4	Trần Lê Quỳnh Thi	██████████	██████████	██████████	██████████		
5	Phạm Hoàng Hà	██████████	██████████	██████████	██████████		
6	Nguyễn Gia Hán	██████████	██████████	██████████	██████████		
7	Đặng Minh Huy	██████████	██████████	██████████	██████████		
8	Nguyễn Phú Thịnh	██████████	██████████	██████████	██████████		
9	Phạm Khánh Ngọc	██████████	██████████	██████████			

2.3. Discussion

The information obtained from the assessment will help the manager to adjust the school's educational plan, adjust the school curriculum to improve the level of competency development for each target group.

The interpretation of the students' individual assessment (Table 7) will be used to determine the current development area and the surrounding development areas of each student. It also helps teachers to consider and make a reasonable pedagogic intervention plan, compatible with each student. In addition, students and teachers can work together or independently to look at progress and set goals for further learning.

In a classroom, there may be many students at the same level of component competency development. For example, the form explaining and reporting the problem solving competency and creativity development of the class (Table 8) shows that 10% of the students attained level 2, 30% of the students reached level 3, 30% of the students achieved level 4, and 30% reached levels 5 and 6. Based on the position of each group, the students at the same level 3 have different surrounding

development areas, so the plans to support the children are different.

3. Conclusion

Problem solving competency and creativity is one of the important competencies that need to be set up and developed among high school students. Studying methodology of competency approach and assessment, we have identified the development pathway and the problem solving competency and creativity standards include 6 levels and 10 behaviors with specific quality criteria; identified methods, tools for evaluating problem solving competency and creativity, used methods of checklists on behaviors and situational assessment; performed pedagogical experiments at Ngo May Secondary school, Quy Nhon City, Binh Dinh Province. The obtained experimental results and feedback from teachers and students show that the competency evaluation process is feasible, which allows us to place our trust in our research. The assessment toolkit for problem solving competency and creativity is under research for improvement and put in experiment.

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