DEVELOPING CRITICAL THINKING COMPETENCE THROUGH USING THE EXERCISE IN TEACHING CHEMISTRY IN HIGH SCHOOL

PHÁT TRIỂN NĂNG LỰC TƯ DUY PHẢN BIỆN THÔNG QUA VIỆC SỬ DỤNG BÀI TẬP TRONG DẠY HỌC HÓA HỌC Ở TRƯỜNG PHỔ THÔNG

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Received 30/10/2015, Peer reviewed 30/12/2015, Accepted for publication 05/01/2016.

ABSTRACT

The usage of the exercises in teaching chemistry in high school is one of the many viable methods to help the development of critical thinking competence proceed faster, easier and more efficient. This report introduces the using of chemistry exercises in order to develop crictical thinking competence based on the research results about: the concept, the structure, the manifestations of critical thinking and in compliance with the 5 principles and 10 steps of the process of developing competence.

Keywords: *competence, critical thinking competence, chemistry, chemical exercise.*

TÓM TẮT

Việc sử dụng bài tập trong dạy học hóa học ở trường phổ thông là một trong những biện pháp khả thi giúp quá trình phát triển năng lực tư duy phản biện diễn ra nhanh chóng, dễ dàng và đạt hiệu quả cao. Bài báo này giới thiệu cách thức sử dụng bài tập hóa học theo hướng phát triển năng lực tư duy phản biện cho học sinh phổ thông dựa trên kết quả nghiên cứu về: khái niệm, cấu trúc, các biểu hiện của năng lực tư duy phản biện và tuân theo 5 nguyên tắc và 10 bước của qui trình phát triển năng lực.

Từ khóa: *năng lực, năng lực tư duy phản biện, hóa học, bài tập hóa học.*

1. INTRODUCTION

Chemistry is an experimental science, which means every doctrine, law, concept, and notion comes from phenomena, experiments as well as actual production processes. In order to study chemistry, learners must have the ability to observe, analyze, evaluate, judge, and rationally apply chemical knowledge to produce accurate and scientific results. Therefore, the development of critical thinking capability is one of the optimal solutions to assist students in practicing necesary skills as well as in gaining precise and profound view about the nature of chemical objects.

Nevertheless, critical thinking education in schools is being unattended, since it requires not only proactivity and creativity from learners, but also time and effort from teachers.

Stemming from the above reasons, we realized that the use of exercises in teaching chemistry in high school is a feasible method which can promote the process of developing critical thinking competence to take place quickly, easily and effectively.

2. SCIENTIFIC BASIS OF THE DEVELOPMENT OF CRITICAL THINKING COMPETENCE FOR HIGH SCHOOL STUDENTS.

2.1. The concept of critical thinking competence

According to Ms. Tran Thi Tuyet Oanh, "The capacity for critical thinking is the ability to assess of human, showing the positive interaction of humans about the world around them" [3]. Based on that together with the

peculiarity of chemistry, our ideas suggested that: "The critical thinking competence is the ability to perform tasks of thinking (analysis, synthesis, comparison, generalization, abstraction) to make comments, conclusions and optimal resolution to tackle problems arising in the process of learning chemistry ". It is among one of the abilities, which demands intensive efforts of mental activity, and also is the foundation of self-education process at higher education level for students.

2. 2. Structure of critical thinking competence

Based on the concept of critical thinking competence, Chemistry program for high schools, the result of the meta-analysis of responses from 56 postgraduates majoring in "Theory and Teaching Methodology of Chemistry" 23th course (2013-2015); 24th course (2014 - 2016) of University of Pedagogy (UP) in Hochiminh City and from 15 experts in "Theory and Teaching Methodology of Chemistry" at Hanoi University of Pedagody, Hochiminh City University of Pedagody, and Hue University of Pedagody, we have identified the structure of the critical thinking capacities as follows:

If Chemistry program is approached from outputs, or in other words, from orientation of developing learners' ability, critical thinking competence includes: the abilitity to analyze chemical matters, the ability to assess chemical matters, and the ability to solve chemical matters. We call this the developmental structure of critical thinking competence. In which:

The abilitity to analyze chemical matters is the ability to detect the nature of the relationships between objects in various chemical matters based on the knowledge of all disciplines.

The ability to assess chemical matters is the ability to use scientific arguments to defend opinions, personal judgment, thereby offering valuable conclusions about chemical matters being under examination.

The ability to solve chemical matters is the ability to detect and implement innovative schemes to overcome the internal shortcomings in chemical matters.

2.3. The expression of critical thinking competence

Based on the determination of the structure of critical thinking competence, psychophysiological characteristics of high school students, high school chemistry program along with the employment of expert methods, we have identified the expression of critical thinking competence as follows:

Table 1. The expression of critical thinking competence

The component abilities	The expressions
The abilitity to analyze chemical matters	1- Recognize the core operating rules of chemical matter. 2- Raise questions related to chemical matter being under examination. 3- Explain chemical matter.
The ability to assess chemical matters	4- Identify limitations. 5- Defend personal opinion and judgement. 6- Conclude chemical matter being under examination.

The ability to solve chemical matters	7- Propose different scientific hypotheses. 8- Develop problem solving plan. 9- Execute the plan independently and creatively. 10- Self-adjust the plan in case it did not successfully solve the matter.

2.4. Principles of critical thinking competence development

To ensure the feasibility and science of critical thinking competence development of schoolchildren, we identified a number of methodological principles as follows:

Principle 1. Ensure the characteristic of the Chemistry

Chemistry is an empirical science, providing literature, laws, concepts, concept of quality as well as variation among substances. This makes the subject of awareness becomes microscopic and abstract. In addition, all of them are derived from phenomena, experiments, and actual production process. Therefore, to achieve high efficiency in the process of learning and study chemistry, it is necessary for learners to possess skills such as: observe, analyze, evaluate, generalize, abstract, ... In order to fulfill such demand, we recognize that the development of critical thinking competence has always attached to theory and experiment so as to help learners gain precise, thorough, and comprehensive view about chemical matters.

Principle 2. Ensure the target-orientation of the program

The goal of the program is to create a favorable environment to promote the comprehensive development of the abilities and qualifications of learners through the provision of basic chemical knowledge together with training of specific skills. Therefore, the development of critical thinking competence of students is effective only when the proposed measures aimed at target standard knowledge, skills and attitudes required by the program.

Principle 3. Ensure the pedagogics

This principle requires the development of critical thinking competence to match the characteristics of psychophysiology and cognitive ability of each student [1]. Hence, the content knowledge as well as teaching objectives in each measure should be distributed and arranged in order from simple to complex and from concrete to general. This will maximize the activeness of student, along with stimulating the passion and creativity towards the subject.

Principle 4. Ensuring the feasibility

This principle requires the critical thinking competence development of students to start from the understanding, analyzing and assessing the situation of student capacity development high schools. Therefore, the measures proposed always stem from: regional characteristics, facility conditions, teaching staff, ... in schools.

Principle 5. Ensure objectivity and accuracy when assessing the development of critical thinking competence

Aside from proposing effective and possible measures, it is crucial to ensure the accuracy and objectivity when evaluating the development of critical thinking competence. To ensure this principle, the assessment should be directed towards following requirements:

- The accuracy of ability assessment scale should be confirmed when measuring the expression levels of learner's competence. To fulfill this, the structure of the rating scale must be scientific, apparent, able to express the close relationship between goal - content - method – organizational form, own a reasonable correlation between evaluation criteria. Besides, the terms used in the rating scale

should be understandable and scientifically accurate [1].

- Each assessment criteria must be stated in specific scores corresponding to action performance result of learners. This will ensure the objectivity in the evaluation process.

- Diversify and combine different assessment tools (tests, study product, observation table, comments ...) in order to ensure the credit when evaluating competence. Moreover, students should be emotionally satisfied, positively encouraged in learning, strengthen credibility and the trust of students to teachers.

2.5. The process of developing the critical thinking competence

Based on theory, practice, and competence development principles above, we build the development processes of critical thinking competence for students as follows:

Step 1. Employ survey method by questionnaire to consult the chemistry teacher of high schools as well as experts in Theories and teaching methodology about the structure, expression, rating scale for critical thinking competence of high school students.

Step 2. Propose measures to develop the critical thinking competence.

Step 3. Employ expert method: consult the chemistry teacher of high schools as well as experts in Theories and teaching methodology about the proposed measures. After that, adjust the first time according to the suggestions from the experts.

Step 4: Test Chemistry teaching methods in schools, as follows:

- Plan to develop the critical thinking competence is showed through lesson plans, Chemistry lesson plans;

- Select Chemistry teaching methods, exercise forms, design lesson plans, design tasks, situations, exercises for students.

- Design measurement tools to assess the development of critical thinking competence.

Step 5: Draw the lessons learned after receiving test results of each measure.

Step 6: Employ mathematical statistical method in order to select the optimal, feasible and efficient measures to develop the critical thinking competence of high school students.

Step 7: Add, modify and finalize measures to ensure the science, effectiveness and feasibility.

Step 8: Integrate measures into teaching: organize, monitor and guide students to perform learning activities.

Step 9: Assess the development of critical thinking competence of students by tools: observation checklist; learning profile of student; self-evaluation of students; test.

Step 10: Gain experience, adjust and improve. Continue to implement activities to develop the critical thinking competence of students.

3. USE CHEMICAL EXERCISES TO DEVELOP THE CAPACITY FOR CRITICAL THINKING

3.1. Classification of critical thinking competence developing chemistry exercises

Based on the structure, expression of critical thinking ability and chemical problem solving method, we divide this type of exercise into 3 categories:

a. Counter-evidence exercises are exercises which contains two factors (conditions, assumptions, conclusions, answer; solution) that can be true or false, the task of learners is to apply the knowledge along with the chemical brainstorming skills (calculations, reasoning, abstraction, ...) to prove either elements to be right or wrong, thereby concluding the remaining element is contradictory.

b. Analogical exercises are chemical exercises which contain elements (conditions, assumptions, conclusions, answer; the answer) that have complementary, supportive, and dialectic relationship. However, there is only one correct element while the rest is incorrect. Learner's task is to explain, prove,

and conclude about the truth-value of each element corresponding to the situation at hand.

c. Exercises contain erroneous element are the chemistry exercises which are based on students' mistakes in the learning process. The learner's task is to detect and explain the mistakes that based on research, analysis, evaluation of the relationship among the mistaken elements in situations in question. From there, students will propose and implement the best solution to overcome the shortcomings in the situation in question. Based on the analysis and synthesis of comments from teachers, we learned that there are 3 kinds of common mistakes in high school students, including false perceptions, erroneous calculations, and erroneous chemical practice.

3.2. The purpose of using chemical exercises to develop critical thinking competence

a. For teachers

- Help teachers to be flexible, creative, and able to easily organize learning activities for students in various forms (individual, in pairs, in groups).

- Teachers can make conclusions quickly and easily, have accurate and comprehensive assessment of the development of critical thinking ability of students through homework with ability rating scale.

- Teachers can easily determine student's attempts and progress through the results of the exercise performed by students. Based on such results, teachers offer words of encouragement, encouraging and guiding students to overcome difficulties in the learning activities.

b. For students

- Help students develop in turn components of critical thinking competency through forms of exercise.

- Help students easily, flexibly, and innovatively manipulate chemistry knowledge in different situations as well as learning tasks.

- Help students with general, accurate, and comprehensive view about chemical objects when accessing knowledge from different sources.

- Retrain students with a positive attitude, love for the chemistry through developed ability to sense, be aesthetic, be sensitive and subtle before changes of experiments, special chemical phenomena.

3.3. Design tools and rating scale for critical thinking competence when using chemical exercises

Based on theory, scientific basis of the research along with teaching goal of high school chemistry program, we have built tools and rating scale for chemical critical thinking competence assessment for students as follows :

Table 3. *Critical thinking competence valuation when using chemical exercises (0: Not perform, 1: incorrectly perform; 2: correctly yet incompletely perform; 3: perform accurately and completely)*

The component abilities	Types of exercises	Solving chemical problem activities	Rating scale of activities			
			3	2	1	0
The abilitity to analyze chemical matters	Counter-evidence exercises	Correctly establish two cases which can be perform in the same problem.				
		Correctly reason either cases.				
		Conclude about the truth-value of either cases.				

The ability to assess chemical matters	Analogical exercises	Correctly and sufficiently identify errors in the problem.				
		Apply knowledge and skills to prove correct elements in the problem.				
		Correctly solve the problem based on correct elements.				
The ability to solve chemical matters	Exercises contain erroneous element	Suggest eliminating incorrect elements in the problem.				
		Develop solutions to overcome mistakes in the problem.				
		Perform solutions independently and creatively.				
		Optimize solutions to cope with practical situations.				
		Total				

Based on building assessment tool for critical thinking capacities mentioned above, we come up with conclusions about the critical thinking competence of students, corresponding to the score obtained as follows:

***Table 4**. Rating scale of critical thinking competence of students*

Score	Conclusion
From 0 to 5	Cannot perform critical thinking operation to solve chemical problems.
From 6 to 14	Perform critical thinking operation to solve simple chemical problems.
From 15 to 23	Proficiently perform critical thinking operation to solve complicated chemical problems. However, creativity is limited.
From 24 to 30	Proficiently perform critical thinking operation to solve complicated chemical problems with creativity.

3.4. The process of using chemical exercises for critical thinking competence development

Step 1. Preparation

- Based on the objectives of the program and lesson, teachers select the content to use these types of exercises for developing critical thinking competence accordingly.

- Design learning tasks according to the level of critical thinking ability development (abilitity to analyze chemical matters, ability to assess chemical matters, and ability to solve chemical matters).

- Predict different solutions from students.

- Prepare tools to assess critical thinking competence in each teaching activities.

Step 2. Develop analytical ability and assessing ability

- Teachers use chemical counter-evidence homework respectively to develop the abilitity to analyze chemical matters, and analogical exercises to promote ability to solve chemical matters.

- Students work independently to complete all learning tasks.

- Students receive support from teachers when necessary.

- Teachers combined scores of all students in learning activities with ability assessment tool to draw conclusions about analytical ability and assessing ability of chemical issues sufficiently.

Step 3. Developing ability to solve chemical matters through the use of chemical exercises contain erroneous elements

- Teachers use chemical homework contains erroneous elements for students to recognize and proposed plan to overcome limitations exist in the situation in question.

- Students share solutions with group members.

- Students in the same group will assess the implementation of other students' plans through evaluation forms. The preferred solution is the one with the highest score in the group.

- The group will modify and complete the preferred solution to conduct reports and present.

- Teachers use the assess tool to evaluate problem solving ability of students.

Step 4. Organize students reported plan to overcome mistakes

- Each group will appoint a representative to report on how to overcome the mistake.

- The group will assess each other through observation checklists and evaluation forms.

- Self-evaluation results in step 3 and step 4 is the foundation for teacher to evaluate problem solving ability of students.

Step 5. Teacher assess and conclude about critical thinking ability of students

- Teacher comment and analyze alternatives proposed by students.

- Teachers summarize teacher's assessing activities, self-assessing and mutual evaluation activities of students.

- Teachers make conclusions on critical thinking ability of students based on rating scales.

4. PEDAGOGICAL EXPERIMENT

4.1. Experimental purposes

Assess the feasibility and effectiveness of using chemical exercises in developing critical thinking competence for high school students. In addition, experience gained when using this type of exercise in teaching high school chemistry.

4.2. Experimental Content

We have conducted experiments in teaching advanced chemistry grade 10 as follows:

Table 5. *List of lessons are experimented in teaching advanced chemistry grade 10*

No.	Unit	Chapter	Duration
1	Unit 49. Chemical reaction rate	Grade 10 – Chapter 7. Chemical reaction rate & Balancing Chemical Equation	1 period (45 mins)
2	Unit 50. Balancing Chemical Equation	Grade 10 – Chapter 7. Chemical reaction rate & Balancing Chemical Equation	2 period (90 mins)
3	Unit 51. Practice Chemical reaction rate & Balancing Chemical Equation	Grade 10 – Chapter 7. Chemical reaction rate & Balancing Chemical Equation	2 period (90 mins)

4.3. Experimental subject

We conducted pedagogical experiment in grade 10 (school year 2014-2015) in 4 high schools in Ho Chi Minh City: Luong Van Can (District 8), Trung hoc Thuc hanh - University of Pedagogy HCMC (District 5), Vo Thi Sau (Binh Thanh District), Binh Chanh (Binh Chanh District). We experiment on 4 pairs of experimental classes - control, with each pair of classes equally qualified (based on previous year's average).

***Table 6**. List the experimental and the control class*

No.	High school	Teacher	Experimental class		Control class	
			Class	Number of student	Class	Number of student
1	Luong Van Can	Nguyen Ngoc Anh Thu	10A2	40	10A3	40
2	Trung hoc Thuc hanh -	Nguyen Hoang Hat	10A1	40	10A3	40
3	Binh Chanh	Nguyen Pham Thuy Linh	10B5	40	10B6	40
4	Vo Thi Sau	Nguyen Minh Thanh	10A6	40	10A7	40
Total				**160**		**160**

4.4. Experimental results

Compare data between the experimental class and the control class through t-independent verification, we obtain the following figures:

***Table 7.** Summary of quantities to verify T*

Class	$\overline{x}$	S^2	S	V	$T_{experiment}$	T_{theory}
EC	6.53	0.92	0.96	14.69%	10.68	1.96
CC	5.12	1.89	1.37	26.75%		

Comment:

- Experimental classes have higher average scores ($\overline{x}$) and lower standard deviation (S) as opposed to control classes. This means that experimental classes have better learning quality than the control counterparts.

- The variation coefficient V of control class are lower than that of experimental class. Thus, experimental classes have more equal quality.

- The verification coefficient is $T_{experiment} > T_{theory}$. Hence, the difference in terms of average scores between experimental classes and control classes is significant in termsof statistics.

With random probability of 1% ($\alpha = 0.01$), the data is reliable and the difference between experimental class and control class is significant. The difference is due to the impacts of the use of chemical exercises rather than random factors.

5. CONCLUSION

Through research, we found that the use of chemical exercises for developing critical thinking competence of students is a good and feasible measure in the development process of general competence as well as critical thinking competence. Thereby, it can contribute significantly in the comprehensive development of learner's competence and qualification that was identified in Resolution 29, the Central Executive Committee 8, XI (2013).

REFERENCES

[1] Nguyen Cong Khanh (2013). "Innovation of testing students to assessment of competence approach". *Seminar "General issues on the construction of high school education program after 2015"*. Ha Noi.

[2] Dang Thi Oanh (2013). "The objectives and standards of high school Chemistry programs after 2015". *Seminar "General issues on the construction of high school education program after 2015".* Ha Noi.

[3] Tran Thi Tuyet Oanh (2010). "Targeting development of critical thinking competence of university students". *Summary record of science seminar "Research, teach and apply Psychology-Pedagogy during international integration phase".* Ha Noi.