Design and using chemistry experiments to develop problem solveing capacity for grade 10 students in Vietnam high school

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ABSTRACT

Developing problem-solving capacity for students is an urgent task for high schools during the period of educational reform in Vietnam. Chemistry experiments contribute to the development of problem-solving abilities for students.

The article presents research results on developing problem-solving capacity for students through the study, design and use of chemistry experiments in teaching 10th grade Chemistry at high schools. The results of the survey on the actual use of chemical experiments are the scientific basis for determining the content and design process of the 10th grade chemical experiment system. The pedagogical experiment was carried out in high schools in the North, Central and South regions of Vietnam with 444 10th graders in the same group before and after using chemistry experiments. The measured results of the pre- and post-criteria assessment using the experiment were grouped into levels indicating that the number of students at the low level shifted sharply to the higher level. We can confirm that the benefits of chemistry experiments depend on the design, use, and learning abilities of each student.

Keywords: problem solving ability; chemical experiments; 10th grade, high school

Introduction

Chemistry is a science with a combination of theory and experiment, with an emphasis on experimental practice. Experiments are one of the teaching aids used to improve the quality of the teaching and educational process in schools (Christina et al., 2014).

The General Education Program in Vietnam (2018) aims to develop students' capacity and promote practicality; helping students develop practical skills to apply chemical knowledge to solve practical problems, meeting the requirements of life. However, the application of experiments in Chemistry teaching in many high schools in Vietnam has not yet been given due attention (An et al., 2021). In addition, the conditions of infrastructure, equipment, chemicals ... have not been fully met, and the quality has not been ensured to properly fulfill the requirements of experimental teaching of the subject (Matt O'Leary et al., 2023).

Many studies have shown that it is necessary to combine many programs, research activities that transmit research to the laboratory, research group meetings, etc (Guo et al., 2021; Mehlich, 2022).

Laboratory practice is an essential component of any high school chemistry course. Laboratory experiences provide students with practice using standard laboratory methods and equipment, to give students a feel for the theoretical relationship and results of a real-world experiment (Giac Cao Cu et al., 2022)

Problem-solving ability is one of the common capabilities of human intellectual activity that requires the mobilization of thinking and creativity to find solutions (Ronny Scherer et al., 2012; Ronny Scherer

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et al., 2014). Chemistry experiment is one of the measures contributing to the development of problem-solving ability for students.

In this study, the problem of designing and organizing teaching activities is clearly stated by the teaching conditions of Vietnamese general education to develop students' problem-solving capacity and demonstrate the effectiveness of teaching activities. of the proposal through analysis of experimental data.

Methods Goals:

The research aims to develop students' problem-solving capacity by designing and using grade 10 chemistry experiments in teaching in high schools.

Design: The research process was carried out through the following stages:

Phase 1: Research the actual situation of using experiments in Chemistry in high schools

Phase 2: Research on building problem-solving capacity structure for high school students.

Phase 3: Building a system of 10^{th} grade chemistry experiments in high school in the direction of developing students' problem-solving capacity.

Phase 4: Using the experimental system for topics to develop students' problem-solving capacity.

Phase 5: Pedagogical experiment and experimental data processing.

Steps to build a chemical experiment system:

- Step 1: Proposing experiments for topics: Derived from the analysis of the structure and content of the lessons in the program and relevant practical knowledge to determine the names and experiments for the topics. .

- Step 2: Determine the problems to be solved in the experiment: Identify the main contents, problems/questions that students need to solve in the implementation of the experiment according to the level and actual teaching conditions. economic.

- Step 3: Build an experimental system for the topics. Design instruction for students that corresponds to the problem solved about the experiment.

- Step 4: Seek expert advice: Conduct consultation with experts: teachers of pedagogical universities and experienced chemistry teachers at high schools.

- Step 5: Check and complete correction: Conduct pilot teaching in high schools, and get feedback from teachers and students to continue editing and perfecting the systems. experimental system.

At the end of the construction process, expert opinions were collected to confirm the practicality, accuracy and science, suitability and feasibility of the experimental system.

Principles of designing chemical experiment systems in high schools in the direction of developing students' problem-solving abilities:

a. Chemistry experiments must adhere to the requirements of the program, the content of knowledge and the objectives of the Chemistry lesson, creating opportunities for students to develop problem-solving abilities.

b. Chemistry experiments must be associated with the development of student’s abilities, especially problem-solving abilities. Chemistry experiments need to contain problems, requiring students to apply knowledge and skills to solve and regularly perform learning tasks with the cooperation of their classmates.

c. Chemistry experiments must be appropriate to the cognitive level and attract students' attention and interest.

d. Chemical experiments should be suitable for the school's facilities, creating conditions for students to exploit and use them and create meaningful products.

Measure: To match the content of the study, the researchers selected a pre- and post-impact test design for a single group. The development of students' problem-solving capacity in the experimental class is assessed by the teacher and self-assessed by the students through the use of a set of tools including: Teacher survey questionnaire about the current situation using experiments, rubric evaluates the development of problem-solving capacity for students before and after the impact.

Sample: The sample includes experts lecturer from universities: Hanoi National University of Education, University of Education - Hue University and Ho Chi Minh

City University of Education and Chemistry teachers from high schools. - evaluate the practicality, accuracy and science, suitability and feasibility of the experimental system.

444 students in grade 10: 72 students from Thuan Hoa High School, Thua Thien Hue Province, 73 students from Krong Bong High School, 75 students from Tran Hung Dao High School, Dak Lak Province, 73 students from Nguyen Khuyen High School, 69 students from Tinh Bien High School, An Giang Province, 82 students from Thanh Nhan High School in Ho Chi Minh City, in the 2021–2022 school year.

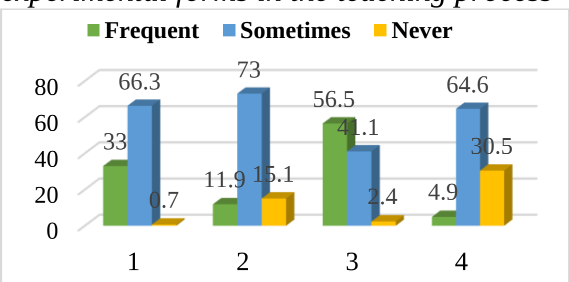
Analysis: Experimental data were processed and analyzed using SPSS 20 software to conclude the effectiveness of teaching organization using experiments to develop students' problem-solving capacity.

Results

Survey results of teachers on the reality of using experiments in Chemistry at high schools in Vietnam

The questionnaire is designed based on the characteristics and properties of the use of experiments in teaching Chemistry. A survey using questionnaires for 285 chemistry teachers in Vietnam, including 0.4% doctorate, 38.6% master and 61.1% Bachelor.

** About the extent to which teachers use experimental forms in the teaching process*



1. Teacher's performance experiment; 2.Research experiment; 3. Practical experiment; 4. Experimental experience

Figure 1: Percentage of teachers using experimental forms in the teaching process

The survey results show that most teachers use student's practical experiments (56.5%) but up to 30.5% of teachers have never used extracurricular experiments, or experience during teaching. This proves that teachers are still used to using forms such as demonstration experiments or students' practical experiments but have not yet focused on using experiments to help students discover knowledge to experience or expand their knowledge.

** About the extent to which teachers use experimental forms in teaching*

1. Research experiment; 2. Illustrated experiment; 3. Comparative experiment; 4. Control experiment

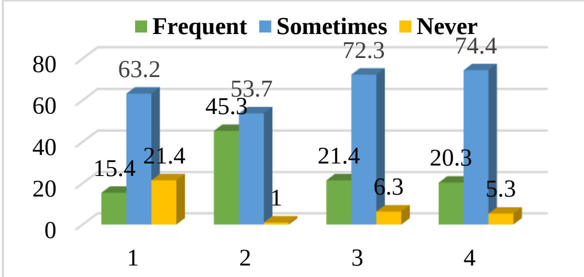


Figure 2. Percentage of teachers using experimental types in chemistry teaching

The results show that the level of teachers using illustrated experiments with the highest frequency (45.3%) is not high (21.4% and control experiments). 20.3%). Thus, the methods of using experiments by teachers are not diversified, limiting the advantages of experiments in teaching subjects.

** About the extent to which teachers build an experimental system according to the topics used in the teaching process*

The survey results showed that the majority of teachers (68.1%) at the level sometimes build experimental systems according to topics. That proves that teachers still mainly rely on textbooks and traditional teaching methods, but have not systematically designed appropriate experiments to use in teaching Chemistry.

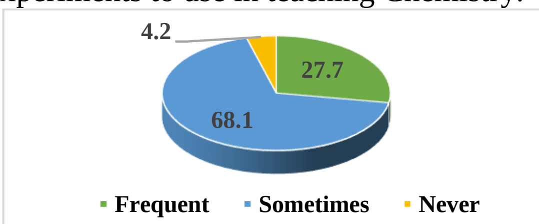


Figure 3. The extent to which teachers develop experimental systems by topics

** About the extent to which teachers use assessment methods when using chemistry experiments in teaching*

The survey in Figure 4 results shows that the level of teachers using the written test method is the highest (56.3% often), followed by observation with a rate of 49.6% frequently. Evaluation of learning records and product evaluation results in a high percentage of teachers who have not used it (31.3% and 22.8%) showing the use of assessment methods when using experiments in teaching. Chemistry needs to be supplemented by the teacher.

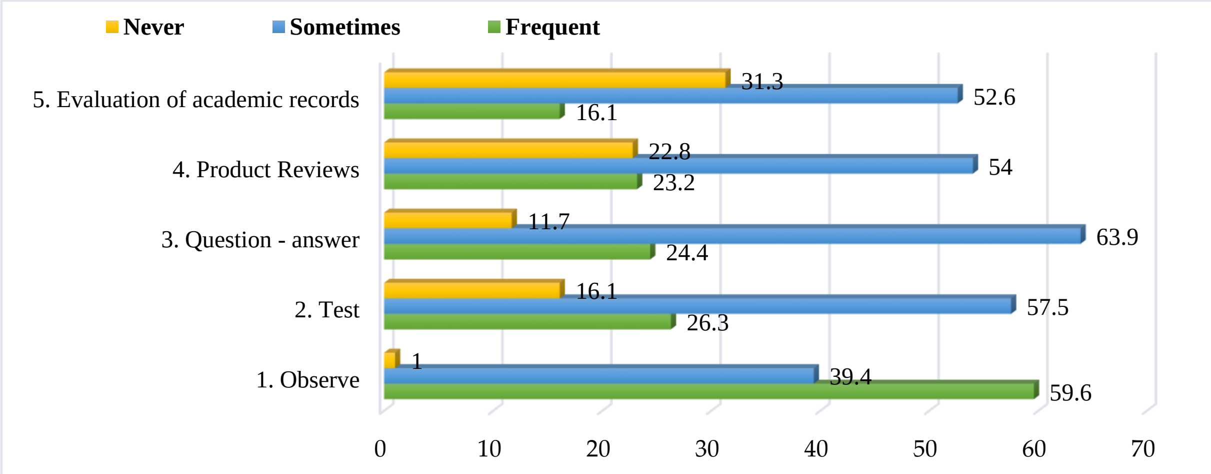


Figure 4. Percentage of teachers using assessment tools

From the actual situation of using experiments in Chemistry in high schools in Vietnam is the basis for us to design and use chemistry experiments to develop problem solving capacity for students.

Table 1. Structure of problem - solving competence of high school students

Component capacity	Criteria of competence
1. Detect and clarify the problem to be solved in the experiment	Criterion 1. Identify problems to be solved in the experiment.
	Criterion 2. Collect and process information related to the content to be solved in the experiment.
	Criterion 3. Propose many valuable questions to clarify the problem posed in the experiment.
2. Proposing and selecting solutions to solve problems	Criterion 4. Propose options/ways to solve the problem.
	Criterion 5. Select the most suitable option/way to solve the problem posed in the experiment.
3. Solve the problem of the experiment.	Criterion 6. Plan and execute the plan.
	Criterion 7. Gather and coordinate necessary resources for the operation
	Criterion 8. Adjust the plan and implement the plan to be effective.
4. Performance evaluation	Criterion 9. Comment and evaluate the problem just solved.

Based on the criteria of the problem-solving capacity structure of high school students, we have built a 10th grade chemistry experiment system. Design the corresponding content to facilitate the use that system of experiments aims to develop students' problem-solving ability.

Table 2. Grade 10 chemistry experiment system in High school

Topic	**Chemical experiments**
Oxidation-reduction reaction	1. Zinc metal reacts with sulfuric acid.
	2. Zinc metal reacts with copper sulfate solution
Chemical energy	1. Quicklime (CaO) reacts with water.
	2. Pyrolysis of potassium chlorate
Chemical reaction rate	1. Effect of concentration on reaction rate.
	2. Effect of temperature on reaction rate.
	3. Effect of pressure on reaction rate.
	4. Effect of surface area on reaction rate.
	5. Effect of catalyst on reaction rate.
	1. Preparation of chlorine.

Element group VIIA	2. Chlorine reacts with metals.
	3. Chlorine reacts with water - The bleaching properties of chlorine water.
	4. Preparation, and bleaching properties of Javel water.
	5. Preparation and properties of hydrogen chloride.
	6. Identify halide ions in the solution.
	7. Compare chemical reactivity between halogens.

Using the experimental system to develop problem-solving capacity for students in the activity "Research on factors affecting the rate of chemical reactions"

Objectives: Students will be able to conduct experiments to research and explain the factors affecting the reaction rate.

Content: Students work in groups. Discuss, and propose experiments to investigate a factor affecting the rate of a chemical reaction. Carry out survey experiments in the laboratory, and record the experimental data. Explain how that factor affects the reaction rate. Prepare a poster to report on the survey experiment.

Product: Study Diary. Posters and student presentations. Mind mapping explores the influence of factors on reaction speed.

Implementation organization:

Learning task: Divide the class into 4 groups of experts. Groups draw factors affecting reaction rate: Concentration (green); Temperature (red); Catalyst (blue); Surface area (purple). The teacher informs the progress of the performance and the evaluation criteria. Students use assessment criteria to guide requirements when performing learning tasks.

Perform mission: Experimental groups: read materials, list chemicals and equipment to perform experiments, and learn precautions to ensure safe experiments.

Groups of experts carry out experiments according to the procedure. The groups completed the report in the study log of the survey results with the following contents:

1. Name of survey element.
2. Survey experiments (chemical equations, chemicals, tools, implementation procedures).
3. Survey results.
4. Conclusion on the influence of the survey factor on the reaction rate.
5. Explain the influence of the survey factor on the reaction rate.

Groups continue to complete posters at home. It is necessary to ensure that all members know the results of the group's practice to prepare for the puzzle group in the next step.

Reports and discussions:

Forming a puzzle group: Each group of experts receives 4 pieces of colored paper (Red - Purple - Green - Blue) according to the correct number of team members. Create 4 new groups by color.

The experts report on the factors that the team has surveyed. While listening to the report, other students in the group record the information and summarize the information in the form of a mind map. Students in the group evaluate your presentation. At the end of each turn, students sit in their seats and pass the posters until the end of their turn.

Total evaluation

Groups of students self-assess their learning activities according to the Assessment Criteria Table.

The teacher summarizes the survey results of the groups and comments on the groups' presentations.

Green group support table - Study on the effect of concentration

Conduct the experiment: Dilute 0.15 M $Na_2S_2O_3$ solution according to the following ratio:

Chemicals	Cup 1	Cup 2	Cup 3
0.15 M (mL) $Na_2S_2O_3$ solution	50	30	10
Distilled water (mL)	0	20	40

Simultaneously pour 10 mL of 0.1 M H_2SO_4 solution into each beaker, stir and stop the timer. Observe what happens, and record the time when the phenomenon occurs.

a. Write the chemical equation that occurs in the experiment.

b. Explain the purpose of conducting the experiment. State the test results. Explain.

Red group support table - Study on the effect of temperature

Conduct the experiment: Take into 2 beakers 20 mL of the oxalic acid solution, and 0.1 M H_2SO_4 solution. Heat the first beaker. Add to both beakers 10 mL of 0.1 M $KMnO_4$ solution and stir well. Observe the phenomenon of the timer to monitor the time when the phenomenon occurs, take a thermometer to measure the temperature in 2 cups and record it.

a. Write the chemical equation that occurs in the experiment.

b. Explain the purpose of conducting the experiment. State the test results. Explain.

Support for the group purpose- Study on the effect of surface area

Conduct the experiment: Weigh about 2 grams of $CaCO_3$ of each type, and put it into the triangle flask (1), (2). Measure about 20 mL of HCl solution and pour it into both flasks simultaneously. Observe the amount of gas escaping from both cylinders.

a. Write the chemical equation that occurs.

b. Explain the purpose of the experiment.

Support team blue- Research on the effect of catalysts

Experiment: Pour about 2 mL of H_2O_2 solution into 2 test tubes (1), (2). Add some MnO_2 powder to the test tube (2). Observe the phenomenon of observing the amount of gas released in both cylinders

a. Write the chemical equation that occurs.

b. Explain the purpose of the experiment. Experiment results? Explain

Hint: does the decomposition reaction take place under normal conditions? The role of MnO_2. Observe the color of the solution after the reaction.

Conclusions and Discussions

Result of expert assessment

After building the experimental system, it was evaluated by experts in terms of practicality, accuracy and scientificity, suitability and feasibility. Responses from 25 experts are listed in Table 3.

The results of the expert's assessment show that the proposed experiments are suitable for the curriculum and teaching conditions in high schools in Vietnam, including practicality, accuracy and scientificness, suitability and practicality possibility.

Assess the development of students' problem-solving abilities

The pedagogical experiment was carried out on 444 10^{th} grade students in high schools with the topics: “Factors affecting reaction rate” and “Elements of group VIIA” – Grade chemistry 10 - High School.

Figure 5. Illustrations of experimental lessons at schools.

Collected data was synthesized and analyzed using SPSS 20 software. Assess problem - solving ability on 56 groups of students when performing experiments (from Level 1: Low ability, Level 2: Medium). to Level 3: high competence), the frequency of each level in each criterion was recorded, and the standard deviation and mean difference were determined and a t-test was performed in assessing whether each criterion before and after the experiment is statistically significant or not. The results are summarized in the following table 4.

Student self-assessment results

The students' self-assessment results are shown in Table 5.

Table 3. Results of expert assessment of 10th grade chemistry experiment system

	Totally disagree	Disagree	Uncertain	Agree	Totally agree
1. Practicality	0	0	0	0	100
2. Accuracy, science	0	0	4	4	92
3. Conformity	0	0	8	12	80
4. Feasibility	0	0	0	12	88

Table 4. The average value before and after the impact through the teacher's assessment.

Criteria	N	Mean		Std. Deviation	Correlation	Sig. (2-tailed)
		before impact	after impact			
1	56	1.37	2.32	.352	.731	.000
2	56	1.16	2.53	.488	.407	.000
3	56	1.78	2.75	.187	.905	.000
4	56	1.76	2.80	.830	.290	.000
5	56	1.48	2.91	.499	.302	.000
6	56	1.42	2.19	.466	.480	.000
7	56	2.01	2.57	.536	.820	.000
8	56	1.46	2.57	.412	.711	.000
9	56	1.60	2.50	.454	.668	.000

Table 5. Results of self-assessment of students' problem-solving ability before and after the impact

Criteria	N	Mean		Std. Deviation	Correlation	Sig. (2-tailed)
		before impact	after impact			
1	444	1.42	2.32	.29913	.808	.000
2	444	1.21	2.56	.47650	.464	.000
3	444	1.69	2.73	.21912	.882	.000
4	444	1.90	2.82	.90925	.154	.000
5	444	1.53	2.92	.49332	.282	.000
6	444	1.44	2.20	.51762	.360	.000
7	444	2.07	2.51	.49685	.907	.000
8	444	1.44	2.56	.44547	.606	.000
9	444	1.59	2.46	.57983	.469	.000

The teacher's evaluation results: the evaluation results of each criterion and the average score of the criteria on the problem-solving ability of students after the impact increased significantly compared to the time before the impact (number of students). Efficiency of the evaluation results after – before > 0. The most significant difference is in the criteria: 2 (Collect and process information related to the content to be solved in the experiment). 5 (Select the most suitable option/way to solve the problem posed in the experiment). This change is not due to randomness but due to the effect of the value of Sig. in the t-test is always less than 0.05. This reflects the development of students' problem-solving abilities through the use of experiments.

The data in Figure 9 show that the students' self-assessment scores for the indicators of problem solving ability after the impact are higher than those before the impact, especially the criteria 2, 5, and 8 This is quite similar to the teacher's assessment and proves once again that the use of experiments has a positive impact on the development of students' problem-solving abilities. By observing students' attitudes and interests and interviewing students in the experiment, we found that the students in the experimental classes were very active, active and excited about performing, and learning, especially with the presentation, debate and evaluation of products and results of experiments.

Thus, the positive feedback of both teachers and students also partly reflects the feasibility and effectiveness of the application of experimental teaching to develop students' problem-solving capacity, contributing to affirming the value of teaching and learning. value and practical significance of this study.

In order to develop problem-solving capacity for high school students through the organization of chemical experiments, it is necessary to have a consensus from setting goals, developing content, planning to organize - practice. implementation of plans and assessment of capacity. In which the focus is on developing content and organizing experimental activities. Through participating in hands-on experiments, students develop problem-solving abilities. Through experiments, students actively explore, discover, and solve cognitive tasks and flexibly and creatively apply knowledge and skills.

However, teaching hands-on experiments to develop problem-solving capacity for students is a long process, gradually implemented through each class hour, and to do well, it needs the efforts of teachers and the standardization of students. active support of the students as well as the facilitated support of the forces involved.

To develop students' ability to solve problems, it should be organized in the direction of discovery and discovery. The experimental system has been built with detailed research problems built by studying the content of the characteristics of the 10th grade chemistry section.

The process of organizing teaching has also been proposed. Effective teaching has been proven through the experimental process at high schools representing three regions of Vietnam; The results show a clear development of problem solving ability of students participating in the experiment.

Acknowledgments: This study belongs to the topic of Hue University, code: DHH2021-03-155.

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