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DEVELOPING REPRESENTATIONAL COMPETENCE FOR STUDENTS THROUGH CHEMISTRY EXERCISES THEME ELEMENTS GROUP VIIA IN GRADE 10

Nguyen Mau Duc[1], Duong Quoc Hoan[1] and Pham Tu Anh[2]
[1]*Faculty of Chemistry, Hanoi National University of Education*
[2]*Marie Curie Hanoi School*

Abstract. Chemistry exercises are valuable tools in teaching and learning chemistry, helping develop students' representational competency per the 2018 Curriculum for General Education. To meet this objective, this article proposes a system of exercises on the topic of "Elements in group VIIA". Theoretical research methods provide the basis for building exercises and suggest methods that could be applied to teaching and learning processes. Statistical and practical techniques are used to test the feasibility and effectiveness of the study. The post-experiment was carried out at Kim Bang A High School with the participation of 41 students. Through statistical processing, the post-experimental evaluation shows that there is an improvement in students' representational competency. Specifically, the average score of the competency to apply knowledge and skills increased from 1.72 to 2.00 with $p = 0.0312$ (<0.05) and ES = 0.82. This is the basis of using the exercise system in teaching, which could be further utilized in other topics.

Keywords: representational competence, students, Kim Bang A High School, grade 10 Chemistry.

1. Introduction

The 2018 General Education Program has mentioned three components of competence in chemistry: expertise, gaining knowledge and communication, and representational competency (Ministry of Education and Training, 2018). Therefore, developing representational competence is one of the essential goals of teaching and learning chemistry in high schools.

Chemistry exercises have proven to be effective teaching tools for developing students' thinking and core chemistry competencies, which can be applied in real-life situations. By solving problems, students acquire the necessary knowledge and learn how to find solutions to specific issues. Appropriate chemistry exercises can promote the development of students' competencies and improve the assessment of those competencies in chemistry. However, designing appropriate teaching tools, media, or methods and evaluating those specific competencies remain challenging. There have been several studies on chemistry exercises published by authors such as Do Thi Quynh Mai [1], Vu Khanh Duyen [2], Tran Trung Ninh and associates [3, 4], Dang Xuan Thu [5], among others, which highlight the significance of this research.

Despite the importance of developing representational competence in specific topics, the current system of exercises is limited. Therefore, this article consolidates previous studies to establish

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Contact Nguyen Mau Duc, e-mail address: nmduc@hnue.edu.vn

general theoretical foundations. Based on this, a system of exercises is designed and proposed on the topic of "Elements in group VIIA" to enhance student representational competence. The results of experiments demonstrate that the exercise system is effective in developing this competency and can be utilized to evaluate students' competency.

2. Content

2.1. Theoretical basis

2.1.1. Competency and representational competence

**** Competency definition***

According to Bernd Meier and Nguyen Van Cuong [6, 7], the concept of competency refers to the responsible and effective competency to perform tasks and solve problems in various professional, social, and personal situations based on knowledge, skills, techniques, and experience, as well as the willingness to take action. Many scholars and experts utilize this perspective to define the concept of competency.

In addition, the New Program 2018 defines competence as follows: "Competency is the ability to successfully perform activities in a certain context through combining knowledge, skills and personal attributes. There are also other qualities, such as excitement, belief, and will. An individual's competency is assessed through the method and results of that individual's activities when solving problems in their life". Competence is also hidden behind the spirit of readiness and the responsibility to the community and society in successfully solving practical problems/situations.

**** Representational competence***

According to the general definition of competence, representational competence refers to an individual's capacity to identify practical problems related to a subject and utilize the knowledge and skills acquired through learning or personal discovery to solve them.

After analyzing the General Education Program in Chemistry and considering the importance of competence and the competency of application of knowledge and skills, we concur with author Tran Trung Ninh [4] with the rubrics to evaluate students' representational competence in the pedagogical experiment below.

Table 1. Criteria evaluating the representational competence in teaching-based chemistry exercises

Criteria	Performance descriptions	Rating scale
CR1. Recognizing, discovering, and explaining natural phenomena, the application of chemistry in life	Present some of the contents guided by teachers related to natural phenomena.	1
	Identify natural phenomena but do not clearly analyze the nature of the problem.	2
	Identify natural phenomena, and analyze clearly and accurately the nature of that problem. Point out the inconsistency in the situation.	3
CR2. Criticize and evaluate the impact of a practical issue	Present several contents related to practical issues.	1
	Assess the actual problem but not clearly and accurately analyze the nature of the problem.	2
	Strictly argue inappropriate criticisms, compliments, and criticisms. Analyze the influencing factors of practical problems	3

CR3. Explore and discover knowledge related to practical problems	Recall knowledge and skills learned to answer practical problems.	1
	Can use scientific evidence of practical problems but do not find the answer to their research problem.	2
	Find the scientific evidence, and research the scientific basis to connect the knowledge and skills learned with the research problem.	3
CR4. Career orientation after graduating from high school.	Recalling the contents of the teacher's career guidance	1
	Explain or partially analyze the career requirements compared with your competency to orient the right career.	2
	Orient to industries and occupations suitable for interests, abilities, and forte.	3
CR5. Behave responsibly, perform practical problem-solving, the requirements of sustainable development	Some feasible proposals have been proposed, and hypothesis testing measures have been proposed, but the problem has not been solved.	1
	Some feasible proposals have been proposed, and hypothesis-testing measures have been proposed, but the problem-solving implementation has not been successful.	2
	Propose reasonable measures; perform effective practical problem solving and propose new problems.	3

A criterion assessment sheet with five criteria of representational competence, each criterion corresponding to 3 levels, is described to assess the progress of experimental class students through topics (level 1 achieves 1 point, level 2 achieves 2 points; level 3 achieves 3 points).

2.1.2. Chemistry exercise

Chemistry exercises are tasks teachers set for students, forcing students to apply their knowledge and experience and use intellectual/practical actions to solve those tasks to improve their competency creatively. There are many ways to classify exercises, such as theoretical exercises, practical exercises, etc.

Theoretical exercises typically ask about definitions, theories, and principles. Solving this kind of exercise allows students to recall their scientific knowledge, understand scientific theories, and demonstrate knowledge through scientific language. Besides theoretical exercises, practical exercises are related to experiments, and practical situations, which are designed based on the teacher’s intention. To solve those exercises, students need to be able to identify problems, analyse, and think creatively through that, representational competence will gradually be developed. However, previously, chemistry exercises were too focused on theory and calculations. To develop learners’ competency, the new educational program has reshaped the exercises and focused more on helping develop students' competency. As a result, designing chemistry exercises that meet new objectives in the 2018 Curriculum is necessary.

2.2. The process of designing an exercise system

We suggest the general process for designing exercise systems for chemistry topics in Figure 1. There are six steps in the process. Firstly, the requirements for a specific topic must be considered.

Based on these requirements, the levels students need to achieve are built in the second step. After that, contents in the topic that can be converted to exercises are identified. In step 4, the teacher collects the information and selects or designs the exercise based on the appropriate level and content. Two last steps allow for assessing the exercise system before use.

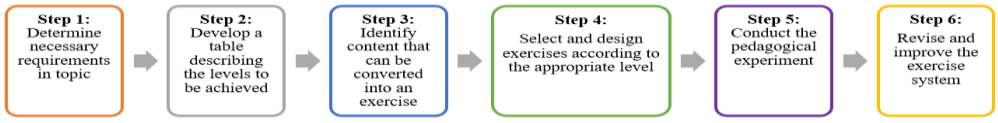

Figure 1. The process of designing an exercise system

In addition, for the exercise to be highly effective and feasible in helping students develop representational competence when building a teacher, it is necessary to adhere to the following principles:

Principles of designing exercises to develop representational competence

Principle 1: Chemistry exercises contribute to achieving subject objectives according to the standards of knowledge and skills and developing students' qualities and competency.

Principle 2: Chemistry exercises must ensure accuracy, scientific, systematicity, update with real life, data suitable for practice, and logic.

Principle 3: The group develops the components of representational competence for students.

Principle 4: Chemistry exercises must stimulate the need to explore and discover science, help students love the subject, and be creative.

2.3. Exercises to illustrate the topic of "Elements of group VIIA"

Exercise 1: The table below shows some information about the elements of group VIIA. Complete predictions about the physical state and colour of astatine under normal conditions.

Element	Physical state	Colour
Fluorine	Gas	Pale yellow
Chlorine	Gas	Pale green
Bromine	Liquid	Red-brown
Iodine	Solid	Black
Astatine	.....	.....

Analysis: This exercise requires students to apply the periodic trend of physical properties in group VIIA to make predictions for the element Astatine. Through this exercise, students will consolidate their knowledge about the physical properties of elements in group VIIA and make predictions based on their relationships. (The exercise focuses on developing CR1 and CR3 of representational competence).

Exercise 2: A student experiments to study the activity of some halogens with chemicals:

+ Bromine (Br_2), chlorine (Cl_2), iodine (I_2).

+ Sodium bromide (NaBr), sodium chloride (NaCl), and sodium iodide (NaI).

Each halogen, in turn, was added to the halide salt solution. The results are recorded in the table below:

	Sodium bromide	Sodium chloride	Sodium iodide
Bromine	-	-	+
Chlorine	+	-	+
Iodine	-	-	-

(Note: "- " reaction does not occur; "+" reaction occurs)

(i) Based on the results, arrange the activity level of the halogens from low to high. Explain your answer.

(ii) Explain why the student does not need to add the bromine solution to the sodium bromide solution.

(iii) For each reaction, what phenomenon did the students observe?

Analysis: In solving this exercise process, besides applying knowledge about the properties of simple halogens to explain the phenomena in practical experiments, students also develop thinking about experimental procedures scientifically, rationally, and predictably phenomena based on scientific knowledge. Through it, students are oriented and inspired about careers related to chemical research. The exercise focuses on developing CR2, CR3, and CR4 of representational competence.

Exercise 3: Elements of group VIIA are called halogens. The halogens form compounds called halides.

The three halogens are represented by the chemical formula X_2, Y_2, and Z_2, respectively.

The above substances were added into separate test tubes containing NaX, NaY, and NaZ, respectively.

The table below shows the results of the experiment.

	X_2	**Y_2**	**Z_2**
NaX	-	+	+
NaY	-	-	+
NaZ	-	-	-

(Note: "- " reaction does not occur; "+" reaction occurs)

(i) Using the information in the table above, arrange the halogens X2, Y2, and Z2 reactivity, respectively.

(ii) Under normal conditions, Z2 is a yellow gas. It was also one of the substances used as a chemical weapon during World War I. Determine the name and chemical symbol of Z2.

(iii) Complete the following table by predicting the boiling point of chlorine, the state of fluorine, and the colour of astatine under normal conditions.

Halogen	**Boiling point (ºC)**	**Physical state**	**Colour**
Fluorine	-188	.....	Pale yellow
Chlorine	.....	Gas	Pale green
Bromine	59	Liquid	Red-brown
Iodine	Sublimation	Solid	Black
Astatine	337	Solid	.....

Analysis: The exercise requires students to apply the periodic trend of physical properties in group VIIA while acquiring more knowledge about the application of chlorine. Through this, students develop the competency to evaluate a problem and explore and discover knowledge critically; At the same time, students will also have a change in how to deal with situations related to chemistry in practice. The exercise focuses on developing CR2, CR3, and CR5 of representational competence.

Exercise 4: Sea water contains bromide ions. People can separate bromine by blowing chlorine into a seawater solution. The ionic equation for the reaction goes as follows:

$$Cl_{2\ (g)} + 2Br^-_{(aq)} \rightarrow Br_{2\ (g)} + 2Cl^-_{(aq)}$$

(i) Name the oxidizing agent in the reaction. Explain the answer.

(ii) The reaction occurs because chlorine is more active than bromine (bromine is below chlorine in group VIIA.) Explain the tendency to decrease activity when going from chlorine to bromine.

Analysis: When solving this exercise, besides the fact that students need to apply the knowledge they have learned (chemical properties of the halogen element) to give appropriate answers and explanations, students also gain deeper knowledge about how to produce bromide in practice. The exercise focuses on developing CR2 and CR3 representational competence.

Exercise 5: For many years, chlorine gas has been used to treat swimming pool water. Chlorine is added to kill harmful bacteria accidentally contaminated by swimmers in the pool. Usually, pool managers will need to check chlorine levels to ensure this chlorine is enough to kill bacteria but not pose a health risk to swimmers. Next, chlorine reacts with water (chlorine then participates in the redox process), establishing equilibrium.

(i) Write the equation that occurs, determine the oxidation number, and state the roles of the reactants.

(ii) Explain why when disinfecting water in swimming pools, people must add chlorine to excess?

(iii) How to know if chlorine is excess or not?

(iv) Explain why people use chlorine to kill bacteria in swimming pools, even though chlorine is toxic to the human body.

Analysis: For this exercise, students need to apply their acquired knowledge to explain practical problems and think about handling chemicals and determining chemical surplus in practice. Thereby developing the components of representational competence. Exercise focuses on developing CR2, CR3, and CR5 representational competence.

Compared with exercises in the coursebook and textbook, the suggested exercises above focus on developing representational competence. Students are forced to solve practical problems to improve the components of representational competence, such as planning experiments; making predictions based on observation and relationships; and explaining phenomena using related knowledge.

2.4. Pedagogical experiment

2.4.1. Objectives and experimental methods

- *Objective:* To test the feasibility and effectiveness of applying the proposed chemistry exercise on the topic of "Elements of group VIIA" to improve the representational competence of 10th-grade high school students. Specifically: evaluate the specific parameters such as reliability, validity, difficulty, and discriminant of each exercise and verify the effectiveness of developing the representational competence.

- *Test subjects:* We experimented at Kim Bang A High School - Kim Bang District - Ha Nam Province based on the characteristics of suitable facilities, students with relatively equal quality, and preparedness to learn the topic we plan to experiment with.

School	Class	Number of students
Kim Bang A High school	10A4	41

- *Experimental content:* students will learn according to the lesson plan we have compiled and use the contract teaching method combined with a system of exercises to develop representational competence in the topic of "elements of group VIIA".

- *Method:* Before the teaching experiment, students' representational competence is assessed by themselves and their teacher using the rubrics. The student also takes an input test. After the teaching experiment, the representational competence assessment and an output test are carried out. The data in the two assessments are recorded and analyzed.

2.4.2. Findings

The pedagogical experiment was conducted in class 10A4 of Kim Bang A High School - Kim Bang District - Ha Nam Province, in the school year 2022 - 2023. To evaluate the feasibility, relevance, and effectiveness of the proposed exercise system to improve the representational competence on the topic of "Elements of group VIIA". The experimental class will be taught according to the process proposed above according to the contract teaching method. Here are some pictures of the pedagogical experiment.

Figure 2. Some pedagogical experiment pictures

From determining the extent of expressing the representational competence and researching other works, we have chosen to use the criterion evaluation sheet with five criteria and three levels (Table 1).

- *Qualitative results:*

After the pedagogical experiment, we conducted interviews with teachers and surveyed students. The response returned is as follows:

Ms Nguyen Thi Nen - A Chemistry teacher at Kim Bang A High School, said: "The exercises in textbooks and workbooks are qualified and effective in developing students' competency. However, the number of exercises is limited, and the exercises do not particularly focus on developing students' representational competence. I found the suggested exercises system bring certain effects and make students more interested in chemistry."

The survey results also show that most students give positive feedback on the exercise system and feel a certain improvement after practicing with the exercises in the system. They also responded that they understood and could apply their knowledge to explain the applications of halogens in real life and were interested in it.

- *Quantitative results:*

Before and after the experiment, we conducted students to assess their representational competence by themselves through the rubrics (Table 1). The results are presented in Table 2.

Table 2. Self-assessment results of students about representational competence

Criteria	Self - assessment					
	Level 1		***Level 2***		***Level 3***	
	Pre-impact	*Post-impact*	*Pre-impact*	*Post-impact*	*Pre-impact*	*Post-impact*
CR1: Recognizing, discovering, and explaining natural phenomena, the application of Chemistry in life	25%	5%	61%	35%	14%	60%
CR2: Criticize and evaluate the impact of a practical issue	40%	14%	42%	60%	19%	26%
CR3: Explore and discover knowledge related to practical problems	12%	16%	69%	30%	19%	53%
CR4: Career orientation after graduating from high school.	77%	9%	23%	81%	0%	10%
CR5: Behave responsibly, perform practical problem-solving, the requirements of sustainable development	75%	44%	13%	37%	12%	19%

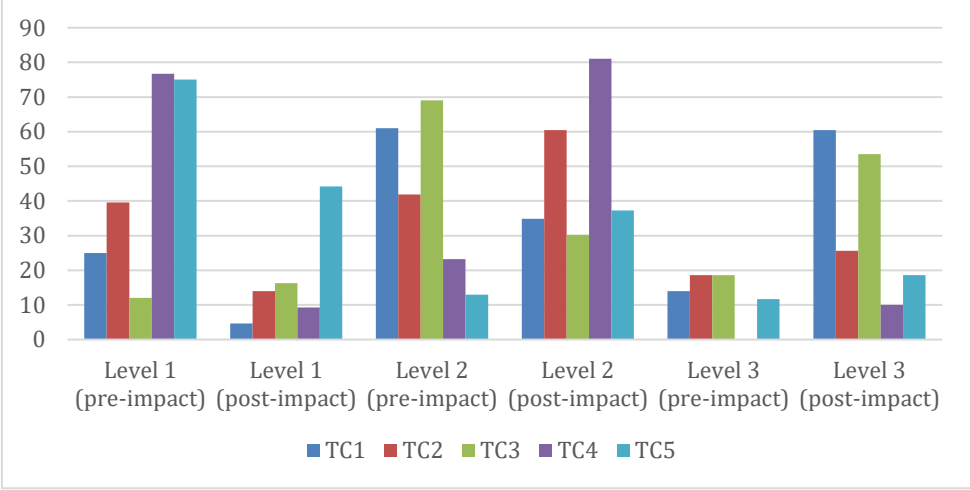

Figure 3. Graph of self-assessment results of representational competence

The results of the qualitative assessment show that students have positive changes after the impact, the percentage of students who evaluate themselves to meet the criteria at level 1 after influence is lower than that of post-impact, and at the same time, the percentage of students who think they have achieved criteria at a higher level (2 and 3) tend to increase after the impact is presented in detail in data Table 3 and Figure 3.

The teacher also assessed the representational competence of students during the experiment through the rubrics (Table 1). The results are presented in Table 3.

Table 3. Typical parameters of the pre-impact and post-impact representational competence of students

Criteria	Pre-impact results				Post-impact results			
	Number of students			*The average score of each criterion*	*Number of students*			*The average score of each criterion*
	1	2	3		1	2	3	
1	3	29	9	2.15	2	23	16	2.34
2	15	18	8	1.83	4	32	5	2.02
3	6	31	4	1.95	9	21	11	2.05
4	31	10	0	1.24	7	34	0	1.83
5	28	8	5	1.44	19	14	8	1.73
Criteria average score				1.72	Criteria average score			2.00
Standard deviation				0.33	Standard deviation			0.21
Dependent t-test (p) = 0.0312								
Effect size ES = 0.82								

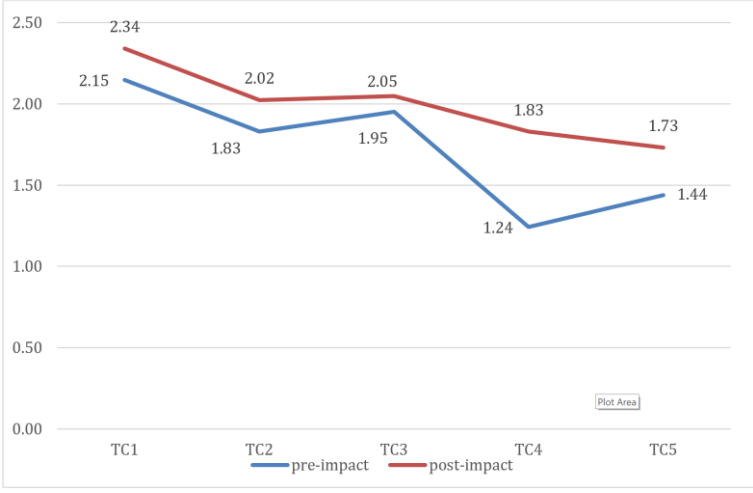

Figure 4. Graph of teacher-assessment results of representational competence

+ The cumulative line graph shows that the practical class postimpact's representational competence is higher than the preimpact's because the line is always on the top. The average score of the criteria post-impact at: 2.00 is higher than this corresponding value pre-impact (=1.72), which means that the impact has brought about a particular development in students' quality.

+ p value < 0.05, the difference in students' representational competence of students' pre-impact and post-impact is significant, and using a system of chemistry exercises in teaching has positively impacted the development of students' representational competence.

To evaluate the feasibility and effectiveness of the influence, we assessed the output results through a test for students in the experimental class to compare with the input results of students. Quantitative assessment results are processed and presented in the table and graph below:

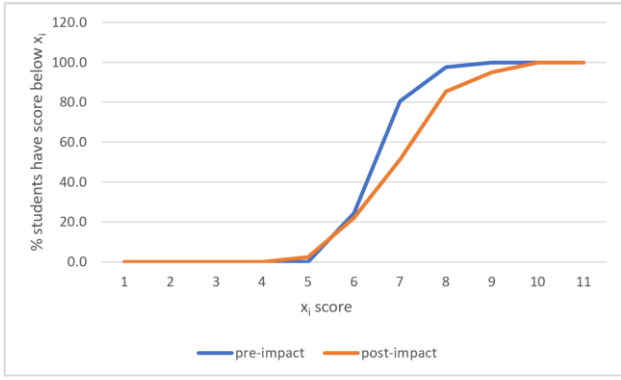

Figure 5 Graph of input and output evaluation results of experimental class

Table 4. Typical parameters of the pre-impact and post-impact test

Value	Pre-impact	Post-impact
Average score	6.44	6.97
Standard deviation	0.65	1.11
Dependent t-test (p)	0.0013	
Effect size ES	0.82	

+ The cumulative line graph shows that the practical class post-impact score is higher than the pre-impact's because the line is always on the top. The average score of the criteria post-impact at: 6.97 is higher than this corresponding value pre-impact (= 6.44), which means that the impact has brought about a particular development in students' quality.

+ P value < 0.05, the difference in students' quality of pre-impact and post-impact is significant, and using a system of chemistry exercises in teaching has positively impacted the development of students' test results.

3. Conclusions

Developing the representational competence of students is one of the essential goals of education in general, and teaching-learning of chemistry in particular, with the characteristics of chemistry, exercises are an indispensable part of contributing to the development of students' representational competence. Through the combination of the contract teaching method and the system of chemical exercises on the topic of "Elements of group VIIA" in the experimental process, the article has shown the progress in students' learning results, developing representational competence; this proves the feasibility of the proposed system of exercises as well as the method of application in teaching practice (ES = 0.82). In the coming time, the author group will expand the study of the exercise system in other chapters of the high school program, as well as the combined methods to apply the exercise system to build a system of exercise practice developing the competency to use knowledge and skills across topics in the new high school curriculum.

REFERENCES

[1] Do Thi Quynh Mai, 2015. Applying some active learning methods from the point of view of differentiated teaching in teaching non-metallic chemistry at high schools. Doctoral thesis. Hanoi University of Education.

[2] Vu Khanh Duyen, 2017. Developing students' competency to apply chemical knowledge through practical exercises in Halogen (Chemistry Advanced 10). Master Thesis. Hanoi University of Education 2.

[3] Duong, M. T., & Tran, T. N, 2022. Designing chemistry exercises in teaching the part "Organic compounds with functional groups" (Chemistry 11) to assess students' representational competence. *The Vietnam Journal* of *Education*, 22(24), pp. 25-30.

[4] Dong Thanh Lan, Tran Trung Ninh, 2020. Using a system of exercises associated with practice in teaching the chapter "Alkali metals, alkaline earth metals, aluminium" (Chemistry 12) to develop students' representational competence. *The Vietnam Journal* of *Education*, Special Issue, September, pp. 57-61.

[5] Dang Xuan Thu, 2022. *Chemistry learning topics 10*. Education Publishing House.

[6] Bernd Meier, Nguyen Van Cuong, 2007. *Training materials for teaching methods*. Potsdam University.

[7] Bernd Meier, Nguyen Van Cuong, 2014. *Theory of Modern Teaching - Reasoning of Objectives, Contents and Methods of Teaching*, Publisher of Pedagogical University.

[8] The Ministry of Education and Training, 2018. General Education Program - Master program. Issued with Circular No. 32/2018/TT-BGDDT dated December 26, 2018, of the Minister of Education and Training.

[9] Vu T.T.H, Nguyen T.D, 2021. Design criteria for evaluating representational competence of students in the “Halogen” topic (Chemistry 10). *The Vietnam Journal* of *Education*, 511(1), pp. 24-29.