Assessing Chemistry Students' Logical Thinking in Colligative Properties of Solutions

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Abstract. Understanding chemistry is a way to develop a solid comprehension of modern sciences. A lot of students are having a difficult time understanding chemistry. Students and teachers must have interactive and engaging learning experiences in this digitalisation era. We experimented with logical thinking between students and teachers to learn more about this. Data obtained from the online questionnaire was then analysed using the GALT (General Ability Learning Test) method. It was found that the level of analysis and critical thinking on colligative properties of solutions of chemistry students was higher than that of chemistry education students.

Keywords: chemistry, colligative, GALT, sciences, properties

1 Introduction

Understanding chemistry is a fundamental aspect of modern science, and students must develop a solid comprehension of the subject. In today's digital age, students are used to interactive and engaging learning experiences, and traditional chemistry teaching methods may not be enough to catch their attention [1]. Students, particularly those studying chemistry, must be able to integrate and correlate basic chemistry concepts such as chemical and physical changes, to promote their creative thinking and problem-solving skills. To accomplish this, educators are progressively looking for ways to efficiently teach chemistry as a subject and support their students' creative thinking and problem-solving skills, leading to a favourable comprehension of chemistry concepts [2].

Recently, numerous countries have prioritised the cultivation of diverse scientific process abilities and thinking skills in their science education programmes. Singapore, Kazakhstan, America, and Canada are notable countries for their proficiency in science education, as highlighted by Yazıcıoğlu and Pektaş [3] for Kazakhstan, America, and

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Özcan and Gücüm [4] for Canada. In addition, science course programmes in Turkey, as revised in 2005, 2013, and 2018 by the Ministry of National Education (MoNE), also strongly emphasised addressing various skills. The talents encompass scientific processes, life skills, and engineering and design. As mentioned earlier, scientific process skills enable individuals to learn about science and comprehend concepts [5]. In this process, problem-solving and thinking skills [6] are cultivated, using engineering and design skills and developing cognitive skills [7]. The ultimate objective is to generate a solution to the problem.

There is a correlation between science process skills, life skills, and engineering and design skills, which are represented as thinking skills such as individuals using their logical thinking skills in the process of assessing situations related to problem-solving, carrying out scientific processes, and making judgments [8]. All the skills described earlier are closely related to thinking skills. It can be asserted that thinking is a mental process and a logical phenomenon in which the unknown is obtained by establishing relationships between propositions. Logical thinking is the key to making the right judgments and solving complex problems. Logical thinking skills, which are one of the thinking skills, are portrayed as the seventh skill that must be possessed by 21st-century individuals among the cognitive abilities of 2020 in the "World Economic Forum" report. In other words, one essential skill that individuals must possess in the future is logical thinking skills.

Therefore, this is the background of a study to find out how far the understanding of students majoring in Chemistry and Chemistry Education is in their understanding in the field of Chemistry, especially in the topic of colligative properties of solution. This is also to measure how deep their understanding of the topic and the logic of thinking it uses so that it can be used to determine how far the logic of thinking used in the thinking process of students as measured by the GALT system analysis, which contains 6 steps including Conservation of Matter, Correlational Reasoning, Proportional Reasoning, Control of Variables, Probabilistic Reasoning, Combinatorial Reasoning [9].

2 Method

This research uses the GALT (General Ability Learning Test) method. This research was carried out in the Department of Chemistry, Faculty of Mathematics and Natural Sciences, State University of Malang, and involved Chemistry and Chemistry Education students from third to first year. This research uses the GALT (Group Assessment of Logical Thinking) method to assess the logical thinking abilities of phase diagram material. Data was collected using an online questionnaire distributed to students via the Google Forms platform, which was held on April 4, 2024. The questionnaire consists of 4 complex multiple-choice questions that require students to analyse the phase diagram displayed and choose the appropriate statement in presenting the diagram. The questions in the questionnaire are designed to measure students' abilities in:

- Understand the basic concepts of phase diagrams: These questions ask about components, phases, equilibrium curves, and Gibbs' phase rule in phase diagrams.
- Analysing phase diagram data: These questions ask students to determine the type of phase diagram, identify the components and phases present in the system, and determine the equilibrium curve.
- Concluding phase diagrams: These questions ask students to conclude the properties of a system based on phase diagrams, such as equilibrium temperature and pressure, phase composition, and phase changes that occur.
- Critical thinking in applying phase diagram concepts: These questions challenge students to apply phase diagram concepts to solve complex and nuanced problems.

The data from the online questionnaire was then analysed using the GALT (General Ability Learning Test) method to determine the average and standard deviation of students' logical thinking abilities. Differences in logical thinking abilities between student groups are also analysed using appropriate statistical tests. The GALT method has 6 steps: Conservation of Matter, Correlational Reasoning, Proportional Reasoning, Control of Variables, Probabilistic Reasoning, and Combinatorial Reasoning.

This research will provide helpful information about chemistry students' logical thinking abilities and chemistry education in phase diagram material. This information can be used to improve the quality of phase diagram learning and develop more effective learning strategies to enhance students' logical thinking abilities. It is important to note that this study only used 4 questions as a measuring tool. Nevertheless, the questions are carefully designed to measure various logical thinking abilities related to phase diagrams.

3 Results and Discussion

Based on the research that we have conducted, we have collected several main points. The first is how the GALT methods can gain logical thinking with much more depth from each student with several questions. The second is how these methods can be one of the alternative strategies for learning to gain ability and attractiveness from each student to understand chemistry materials much better. Then, there is the table reviewing the questions that use GALT methods.

Table 1. Question review table using the GALT method

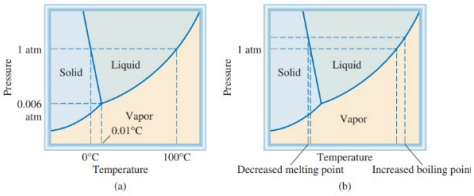
Number	Description	Picture
1	Question and result analysis using GALT methods session 1.	

Fig 1. Water phase diagram

SES 1
Number 1

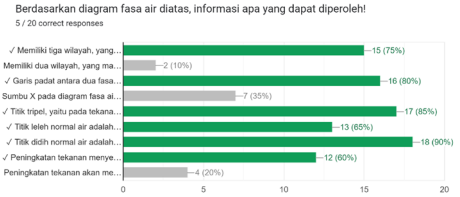


Fig 2. Recapitulation of answers number 1 Session 1
Number 2

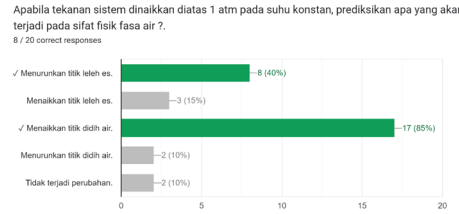


Fig 3. Recapitulation of answers number 2 Session 1
Number 3

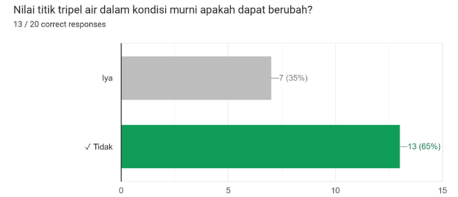


Fig 4. Recapitulation of answers number 3 Session 1

2 Question and result analysis using GALT methods session 2.

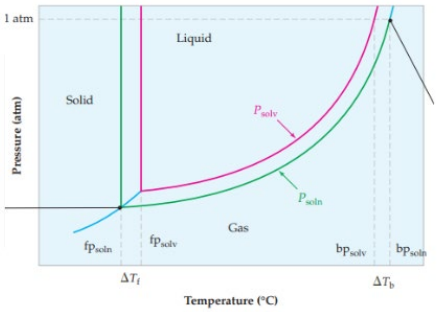


Fig 5. Solvent and solution phase diagrams
SES 2

Number 1

Fig 6. Recapitulation of answers number 1 session 2

From the table can be analysed from each question which one of them is too difficult for the respondent to answer. Besides that, the component of GALT methods is applicable for measuring how far the respondent can use their logical thinking to answer each question we provided. Next, the first question consists of three main questions that have different parameter measures: conservation of matter (Based on the water phase diagram above, what information can be obtained!) and correlational reasoning (If the system pressure is increased above 1 atm at a constant temperature, predict what will happen to the physical properties of the water phase? Can the value of the triple point of water in its pure state change?). The second question consists of one main question with one parameter measure: conservation of matter (From the above diagram, what conclusion can be made?).

Based on the flow of the thought process of the first question in session 1, most respondents can choose the correct answer. Still, if viewed with in-depth analysis, there are several correct answers, with fewer respondents who can use their ability related to logical thinking to finish the questions. Let's look at the first question of session one, which consists of the conservation of matter parameters. There are six suitable options; most respondents can choose the correct answers in the fifth option with the final amount of data being up to 90%, and then the sixth option is the worst, or the lower respondent can choose the correct answers with the final amount data is up to 60%. Next, on the second question, session one, with parameters analysing the same as the first question, there are two correct options. The respondent can mostly answer the second option question rather than the first option question, with the final total amount of data being up to 85%. From these two questions, the first question consists of many options that can fool the respondent's ability, so the distribution of the total amount is much more random than the second question. Then, in the last question of the first session, which consists of correlational reasoning parameters, the respondent can answer this question up to 65%. Therefore, most of the respondents have a higher ability to conserve matter than in correlational reasoning. This could happen because, in correlation reasoning, the respondent needs much more information and depth regarding the main point of the questions.

In the second session, there is just one question that consists of the conservation of matter parameters. This question also has six suitable options, the first question in the first session. This conditioning can fool the respondent's ability as the first question in the first session. Then, from the final amount of data of the questions, the respondent

can answer the right answers in the sixth option, which is the highest total amount compared to the other suitable options. It can be concluded that, from the first and second sessions, most of the respondents understood the basic concept of phase diagrams with conservation of matter parameters. Next, we present the table of the final scores from the two study programs that we have analysed their ability before.

Table 2. Table of final grades from both study programs

Study program	Score of the first session question	Score of the second session question	Final score
Chemistry education	36	15,6	51,6
Chemistry	47,2	26,4	73,6

The table shows that the chemistry students scored slightly higher than the chemistry education students. Besides that, they have excellent analysis and critical thinking skills from the phase diagrams with several parameters that we have conducted before. With this statement, it can be said that the final statement that the major of chemistry is better than chemistry education is not always valid because other researchers can use different ways to analyse their ability related to critical thinking.

4 Conclusion

This study uncovered the level of analysis and critical thinking on colligative properties of solutions between chemistry and chemistry education students. This current study displayed a higher score for chemistry students. However, due to the limited number of respondents, there is insufficient evidence to claim that the chemistry students performed better. Therefore, a future study involving bigger and more representative respondents across universities is suggested.

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