Assessing conceptual and algorithmic understanding of students in senior high school

Nuzulia, M Hasan and A Ismayani
Syiah Kuala University, Jl. Teuku Nyak Arief Darussalam, Banda Aceh 23111, Indonesia
Email: muhammadhasan.kimia@unsyiah.ac.id

Abstract. Learning chemistry involves algorithmic and conceptual understanding, and students are required to master both of them. This study aims to obtain preliminary data about the algorithmic and conceptual abilities of students in solving chemistry problems. This research is part of development research with Plomp model that focuses on the preliminary investigation stage. The data were collected using test, questionnaire, and an interview involving 50 students of a high school in Banda Aceh. The data were analyzed to find the percentage of students’ ability on algorithmic and conceptual understanding. The findings show that 13% of students achieved high algorithmic and high conceptual understanding, 6% of students achieved high algorithmic and low conceptual understanding, and 30% of students achieved low algorithmic understanding. Therefore, it is needed to develop learning materials appropriate to the conditions of students to improve students’ algorithmic and conceptual understanding.

1. Introduction
To succeed academically, high school students must be able to solve both algorithmic and conceptual problems. Conceptual problems require students to understand the concepts of a problem, without requiring them to memorize. To solve conceptual questions, students need to have a strong conceptual understanding of the topics involved [1]. Conceptual problem solving requires a good understanding of the concepts of science and the application of conceptual knowledge. Although conceptual understanding is identified as the primary goal of teaching science, instruction in a chemistry course usually emphasizes complex processes for solving algorithmic problems [2]. Algorithmic problems require the application and manipulation of certain mathematical formulas. Science teachers often assume that students' performance in mathematical problem solving indicates the mastery of chemical concepts. Teachers should think further whether the students understand a lesson or not. Also, teachers are expected to know whether students use concepts in problem solving, relate the concepts to daily life, and use critical thinking [3]. On the other hand, many students solve chemical problems using algorithmic strategies but do not understand the chemical concepts behind their algorithmic manipulations. They also did not understand the algorithmic thoroughly; they only follow what their teachers did [4]. Thus, students have problems both the algorithmic and conceptual parts.

The essential indicators in conceptual understanding problems are an explanation of selected answers, predict events, explaining processes, and being able to connect with other topics. Specifically, there are six types of conceptual questions. The first one is the tiered multiple-choice question. It has several interrelated questions between questions; the first question gives a prompt, and the second question gives the reason for the first question. The second type is the question on particle...
levels that represents chemical situations at the atomic or particle level by using different sizes or colors for circles or spheres representing particles. The third type is the question involving the use of graphs, tables, and other data to forecast or describe phenomena that have occurred in experimental situations. The fourth is the demonstration question, in which students must answer questions after they observe demonstrations, videos or simulations. The fifth is the analogy question. The last one is a series of questions that require students to select an item that will complete the series [1].

On the other hand, the algorithmic indicator utilizes mathematical data and formulas for the solution of problems. The algorithmic troubleshooting strategy requires the application and manipulation of certain mathematical formulas. Many students still lack the conceptual understanding of chemistry. Both teachers and students play an essential role in developing problem-solving skills in chemistry [1].

The US Office of Education and the US National Joint Committee on Learning Disabilities suggests that learning disability is defined as a type of heterogeneous disorder, and contains diverse characteristics among individuals, and student learning outcomes [5]. The effects of learning difficulties include obstacles to listening, speaking, reading, writing, logical thinking, and mathematical ability. Learning difficulties are not always explicit. Therefore, to detect students' learning difficulties, intelligence checking can be performed. Moreover, teachers need to analyze students' skills on a concept before providing a basic concept and correct misconceptions. Then, the teachers need to give an algorithmic problem and students should be able to develop it. So that, the teachers can understand the needs of their students [3].

The purpose of this study is to obtain preliminary data on students' conceptual and algorithmic understanding to be further used to determine appropriate efforts to assist students’ learning. Based on the effort determined, it will be developed learning materials that can assist students in understanding the conceptual and algorithmic understanding. This research is expected to give a starting point for future researchers to conduct more research in this field.

2. Method
This study was part of broader research in the development of learning tools to foster students’ algorithmic and conceptual abilities. The broader research followed stages of Plomp model, that is preliminary research, prototyping, and assessment phase [6]. However, this paper focuses only on the preliminary research stage that shows the importance of learning developed instruments.

This research was conducted in a senior high school in Banda Aceh, Indonesia. The instrument of this research is the test, questionnaire, and interview guide sheet. The test consists of problems that measure the understanding of concepts and algorithms. The participants involved 50 students and were categorized into four groups. The first group is the students who have a high algorithmic understanding with a score of 70-100% on algorithmic problems and who have a high conceptual understanding with a score of 50-78% on conceptual problems. The second group is the students who have a high algorithmic understanding with a score of 70-100% on algorithmic problems and who have a low conceptual understanding with a score of 0-33% for conceptual problems. The third group is the students who have a low algorithmic understanding with a score of 0-40% on the algorithmic problems and who have a high conceptual understanding with a score of 50-78% on conceptual problems. Last, the fourth group is the students who have a low algorithmic understanding with a score of 0-40% on the algorithmic problems and who have a low conceptual understanding with a score of 0-33% for conceptual problems [7].

3. Results and discussion
After the students took the test, their understanding of conceptual and algorithmic was analyzed. The findings show that 13% of the students achieved high algorithmic and high conceptual understanding, 6% of the students reached high algorithmic and low conceptual understanding, and 30% of students achieved low algorithmic understanding. The percentage of the finding is shown in Figure 1. Based on the interview result, the first and second group of students preferred algorithmic rather than
conceptual. However, the second group of students with higher algorithmic understanding was unable to gain a high conceptual understanding [8].

![Percentage of Algorithmic and Conceptual Understanding](image1)

**Figure 1.** Percentage of conceptual and algorithmic understanding of the students.

Students are considered having high algorithmic or conceptual understanding if they have a score of 40-100 and having low algorithmic or conceptual understanding if they have a score of 0-39 [1]. The students who achieved high algorithmic understanding are not guaranteed success in answering conceptual problems [3]. Moreover, the third group of students preferred conceptual understanding. Nevertheless, the third group of students continued to state that the algorithmic problems were easier than conceptual problems because, sometimes, conceptual problems are more elusive than algorithmic problems. In some cases, there were also some students who had high understanding in concept but were not able to use them in algorithmic problems [9].

One of the algorithmic questions used in this study is the combustion enthalpy of fuel of 5.460 kJ/mol and 5.7 grams of fuel (Mr = 144) is burned then the students need to find the resulting combustion enthalpy. This kind of problem only requires remembering formulas and students should be able to solve them if they know the formula. On the other hand, the conceptual problem requires a deeper understanding of concepts. Students are not able to answer if they only memorize the formula without understanding the concept. Example of the conceptual problems is the problem about the magnitude of the enthalpy price as shown in Figure 2 below.

![Energy Diagram](image2)

**Figure 2.** Example of the conceptual problems.

To be able to answer the conceptual problems as in Figure 2, students should understand the concept and be able to read the charts, because the ability to read graphics is part of the understanding of concepts. Many students know that enthalpy change is a product minus reactants, but if they do not understand the graph, then they can not answer the problem. Such a conceptual problem requires a comprehensive understanding. Conceptual problems can be expressed in different forms and types such as pictorial and verbal forms. The problems in the pictorial form are represented using images,
Students’ understanding of thermochemistry might not be improved through the teacher-centered learning. Lack of understanding of students might be caused by the teacher’s teaching strategy that was still not appropriate to the students. This is supported by Bowen and Bunce stating that many factors hinder students studying chemistry namely, adequate skills such as algorithmic, hierarchical structure of concepts, textbooks, and learning methods [9]. This will be an indication for educators to seek other alternative teaching and learning approaches to develop students’ conceptual understanding of chemistry [1]. This thermochemical topic is quite difficult for students. Based on the data obtained in the last two years, daily test value on the thermochemical topic did not meet the established standards of 75 out of 80.

Students had also been distributed a questionnaire to determine the needs of students on this material. The questionnaire used the Likert scale. The results of the questionnaire indicate a score of 4549. The score in the range 3864 to 5152 is categorized closer to agree that means teachers should balance the delivery between algorithmic and conceptual understanding because both are important. Students should not be focused on the understanding of chemistry only but must be both algorithmic and conceptual to understand the chemistry thoroughly. In thermochemical learning, some teachers still deliver the material concentrate only on understanding chemistry. A balance between conceptual and algorithmic understanding is essential in learning chemistry. One of the topics that require the two understandings is thermochemistry [11].

Another study conducted on students at one of the schools in Ankara, Turkey on the topic of atomic structures and periodical tables, the concept of mole, gas laws and solutions have the similar findings. The study found that students’ algorithmic and conceptual abilities were considered high. However, these scores could not be entirely used as a guideline because the participants involved in the study were eleventh grade which had been prepared to enter the university [2]. Another study in Taiwan found that students had higher algorithmic than conceptual abilities [12]. Similarly, 36.8% of high school students in Greece were only able to answer algorithmic problems. A few students were able to answer both with the percentage of 6.4%, and 3.2% of students were able to solve only conceptual problems [6].

Unlike the three studies above, a study in Turkey looked for ways to improve algorithmic skills. The study was conducted on the pre-service teachers in Turkey, and the findings showed that the student-centered learning like Problem-Based Learning (PBL) could improve the algorithmic and conceptual abilities of students in the gas concept topic [13]. The same finding occurred in Malaysia; there were 96% of pre-service teachers who can solve algorithmic questions, and 54% of pre-service teachers who can answer the conceptual question using problem solving approach [1].

The results of this study indicate that students’ conceptual understanding was still low. Therefore, it is needed to consider how to develop students’ conceptual understanding. There are three important points that should be considered in order to improve the conceptual understanding of students: the emphasis on macroscopic, microscopic, and symbols. The macroscopic understanding is something that can be seen and felt. Microscopic understanding is something at the level of atoms, molecules, and kinetic parts. Symbolic understanding is a representation of chemical symbols, stoichiometry, and equations [14]. Furthermore, it should also be noted that learning styles and teaching strategies contribute to the improvement of students’ algorithmic and conceptual abilities. Based on the observations on the teaching strategy, when teachers used teacher-centered learning and provided explanations from the beginning to the end of learning, students’ understanding would not have a significant improvement. Also, teachers should connect the topics with the students’ experience so that the students’ learning in chemistry is more meaningful. Find real examples related to students’ everyday life on chemistry topics is needed, especially on the topics that involve the microscopic and symbolic levels.
4. Conclusion
The findings show that 13% of students achieved high algorithmic and high conceptual understanding, 6% of students achieved high algorithmic and low conceptual understanding, and 30% of students achieved low algorithmic understanding. None of the students has a low algorithmic understanding and a low conceptual understanding. Based on the findings, it is necessary to do research on learning strategy and media that can enhance algorithmic and conceptual understanding of students in thermochemistry. The implication of this research is to develop a lesson with the right approach to improve the students’ algorithmic and conceptual abilities.

Acknowledgment
The authors would like to thank Syiah Kuala University and the Youth and Sports Office in Banda Aceh for their support in making this study possible.

References
[1] Surif J, Ibrahim N H and Dalim S F 2014 Problem Solving: Algorithms and Conceptual and Open-Ended Problems in Chemistry Procedia - Social and Behavioral Sciences 116 4955
[2] Yilmaz A, Tuncer G and Alp E 2007 An Old Subject with Recent Evidence from Turkey: Students’ Performance on Algorithmic and Conceptual Question of Chemistry J. World Appl. Sci. 2 420
[3] Gultepe N, Yalcin C A and Kilic Z 2013 Exploring Effects of High School Students’ Mathematical Processing Skills and Conceptual Understanding of Chemical Concepts on Algorithmic Problem Solving Australian Journal of Teacher Education 38 106
[4] Cracolice M S, Deming J C and Ehler B 2008 Concept Learning Versus Problem Solving: A Cognitive Difference Journal of Chemical Education 85 873
[5] Widayanti C G, Diana R and Siswati 2012 Profil Inteligensi Pada Siswa dengan Kesulitan Belajar di SD Negeri Gisikdrono Semarang Jurnal Psikologi Undip. 11 1
[6] Plomp T 2010 Educational Design Research: an Introduction (Netherlands: Institute for Curriculum Development)
[7] Papaphotis G and Tsaparlis G 2008 Conceptual Versus Algorithmic Learning in High School Chemistry: The Case of Basic Quantum Chemical Concept Chemical Education Research and Practice 9 323
[8] Usman H and Purnomo S A 2012 Pengantar Statistika (Jakarta: PT Bumi Aksara)
[9] Chiu M 2001 Algorithmic Problem Solving and Conceptual Understanding of Chemistry by Student at A Local High School in Taiwan Proc. Natl. Sci. Counc. 11 20
[10] Bowen C W and Bunce D M 1997 Testing for Conceptual Understanding in General Chemistry The Chemical Educator 2 1
[11] Haláková Z and Proksa M 2007 Two Kinds of Conceptual Problems in Chemistry Teaching Journal of Chemical Education, 84 172
[12] Johnstone A H 2006 Chemical Education Research in Glasgow in Perspective Review of research
[13] Chiu M H 2001 Algorithmic Problem Solving and Conceptual Understanding of Chemistry by Students at a Local High School in Taiwan Proc. Natl. Sci. Counc. 11 20
[14] Bilgin I, Senocak E and Sozbilir M 2009 The Effect of Problem-Based Learning Instruction on University Students’ Performance of Conceptual and Quantitative Problems in Gas Concepts Eurasia Journal of Mathematics, Science & Technology Education 5 153
[15] Johnstone A H 1991 Why is science difficult to learn? Things are seldom what they seem Journal of Computer Assisted Instruction 7 75