



Study of Conceptual Change in Chemistry for Class XI Science High School Students

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Abstract

Varied initial concepts can be an obstacle or support in understanding a new concept. The study of changes in students' chemical concepts was carried out on thermochemical material. This study aimed to examine changes in students' thermochemical concepts in each subject of high, medium, and low ability. Qualitative descriptive research with mixed methods was conducted on SMAN 1 Bumi Raya Morowali, Central Sulawesi students. The study began by giving an initial test to all students of class XI IPA 1 and 2, as many as 60 students, to obtain initial concept data and the basis for grouping subjects on each ability criterion (high, medium, and low). Every two people from each ability group in semi-structured interviews. Thermochemical material is re-taught using a metacognitive skill learning model and given a final test and interview to get concept data after learning to assess conceptual changes. Five concepts become variables in this study: the heat of reaction, enthalpy of reaction in a calorimeter, Hess's law, energy diagrams, and bond energies. The results showed that concept changes occurred in all high, medium, and low ability subjects. Changes in students' conceptions occurred in the concepts of the heat of reaction, reaction enthalpy, calorimeter, Hess's law, energy diagrams, and bond energy. The most significant conceptual change occurred in the subject of medium ability and low ability, namely the concept of bond energy.

Keywords: Concept change, thermochemistry, high ability, medium ability, low ability

Introduction

Chemistry is part of Natural Sciences (IPA) which studies material, namely the nature of matter, material structure, material composition, material changes, and the energy that accompanies material changes (Depdiknas, 2003). Thermochemistry is part of natural science, in this case, chemistry which studies the relationship between chemical reactions and the accompanying heat (Sudarmo, 2017). This knowledge can be obtained through experimental results and reasoning. One of the goals that must be achieved in learning chemistry is mastery of the concepts that have been studied. The emphasis on concepts in chemistry learning is significant, so the ideas need to be understood and mastered by students in solving and providing solutions to every problem.

Wibowo et al. (2015) suggest that the chemistry learning received by students tends to be filled with closed facts and chemical formulas that have nothing to do with their lives, so students tend to memorize, then easily forget what they have learned. Memorizing is one of the fastest ways to

remember the information given. Still, in chemistry learning, students are faced with problems that must be solved with a better understanding of concepts. Sutrisno et al. (2018) state that understanding the concept is one of the cognitive aspects of implementing learning activities in schools. Anderson and Schonborn define concept understanding as an ability to understand and integrate concepts with other related concepts to develop a clear framework and transfer and apply knowledge about concepts to solve problems (Ijirana, 2016). Understanding the concept can be done by providing information related to the topic of learning in the teaching and learning process takes place. However, sometimes the data obtained is misunderstood by students, causing conceptual errors (misconceptions), and even students also experience not knowing the concepts that have been given. Sutrisno et al. (2018) suggests that misunderstandings can occur because of preconceptions and school-made misconceptions. It often happens because every student already has an initial concept called a preconcept. When he receives new information, students will connect the

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concepts that already exist in him with new concepts that can lead to misconceptions and do not know the concept. To direct students to understand concepts that follow the concepts of experts, in this case, experts in the field of chemistry, that is necessary to make an effort to change the concept.

Kuhn first proposed the conceptual change in Nadelson et al. (2018), which stated that the concepts embedded in scientific theories change meaning when the idea changes. Concept changes can occur due to accommodation and assimilation (Posner, 1982; Vosniadou, 1994; Vosniadou, 2007; Vosniadou, 2013; Liljedahl, 2011; Eymur & Geban, 2017; Ijirana et al., 2021). The assimilation process occurs when the conceptual structure assimilates the new concept. In contrast, the conceptual system is accommodated if the idea understood by students is in conflict with the new concept being studied. The accommodation process occurs depending on conditions, namely: students' dissatisfaction with existing ideas (dissatisfaction), the sense of the new concept (intelligibility), clarity of new concepts (plausibility), and the benefits of new concepts (fruitfulness) (Nadelson et al., 2018). In addition to these conditions, another factor that affects the process of changing ideas in students is that students' long-term memory is not formed in a knowledge network (network of knowledge), so the concepts that exist are only associative memories (Lestari & Linuwih 2014). Therefore, ideas that students have owned for a long time can be replaced with ideas that have just been received to allow conceptual changes to occur in students. Conceptual change is also fundamental because there is the fact that students' ideas before being taught are contrary to scientific truth, especially in teaching science (Küçüközer & Kocakulah, 2008). Özdemir & Clark (2007) also stated that learning science is a gradual process in which children's interpretations obtained from everyday experiences are continuously enriched and restructured so that the concept will reach an idea that is by the concept of scientists. The achievement of concepts following scientific concepts can be a picture of the occurrence of conceptual changes in students. Conceptual change does not occur immediately and briefly but through a series of gradual processes with various factors that support these changes, one of which is the learning process. Several studies state that a good learning process includes applying the learning model to the teaching and learning process in the classroom. The following is research on the use of learning models. In their study, Veenman & Spaans (2005) stated that there was a positive effect on the learning and performance of high school students' mathematics tasks taught with metacognitive skills. In addition, Ijirana (2017); Ijirana & Nadjamuddin (2019) showed that the learning of metacognitive skills applied to students effectively improved problem-solving abilities and understanding of concepts in chemistry.

Research on conceptual change has been carried out by Hudha et al. (2016). Their research

results stated a shift in student concepts after exact problem learning through integrative learning. In thermodynamics teaching, Lestari & Linuwih's (2014) research on conceptual changes in thermodynamics found significant differences in changes before and after learning the concepts of temperature and heat in superior-class high school students. Hadi (2016) showed that there was a change in the concept from the initial idea, which is not correct to be much more perfect in understanding the concept of the triangle's height. In addition, in their research results, Muchyar et al. (2015) stated that conceptual changes occur in students taught with practical and student-centered instructional activities. Küçüközer & Kocakulah (2008), science educators stated the importance of the study of conceptual change because students' pre-teaching ideas contradict scientific truth. It is proven by the difficulty of changing these ideas with traditional teaching methods and creating problems in learning new topics.

Based on the description above, to be able to experience conceptual changes in understanding the concepts in each lesson, an effort can be made, one of which is to choose a learning model that will be used in the learning process. One of the practical learning models applied to thermochemical material is the metacognitive skills, learning model. In this study, researchers will examine the conceptual changes of class XI science students on thermochemical material after learning the metacognitive skills model.

Methods

This type of research is descriptive qualitative research with a mixed-methods approach in class XI IPA SMAN 1 Bumi Raya, Morowali Regency. The mix method approach is used to obtain supporting data in the form of quantitative data. That is used as a basis for grouping students into three ability criteria (high, medium, and low) as well as the primary data in the form of qualitative data, namely initial concept data and concepts after learning. The grouping of students' ability criteria was adapted from the set of Sudijono (2009). The research sample used a purposive sampling technique, namely sampling data sources with specific considerations (Sugiyono, 2015), to get the two subjects on each ability criterion. Respect for taking matters in class XI IPA because this class has received previous thermochemical material and is considered to have known and mastered the concept. The study began by giving a classical pre-test to 60 students of class XI IPA 1 and 2 with a total of 28 male and 32 female students so that 6 students were obtained on the criteria of high ability, 48 students of moderate ability, and 6 students of low ability. For each ability criterion, two students were selected so that all subjects totaled 6, consisting of 2 male students and 4 female students. The six issues were subjected to semi-structured interviews to confirm the answers to the initial test results and to ensure the data's validity.

The test consists of 5 questions in the form of descriptions, coded with the term concept problem (CP). Conceptual problems (CP) consist of CP1, CP2, CP3, CP4, and CP5, the question codes for each thermochemical concept given in the pre-test and post-test.

Furthermore, the learning process was carried out for 6 meetings by applying the metacognitive skills learning model to all students, including the six research subjects. After that, a final test was carried out on all students and the six research subjects to get concept data after learning. Afterward, semi-structured interviews were conducted with the six subjects to clarify the results of the final test answers. After all, data was obtained from each series in the study; it was continued by examining the concept changes that occurred based on the initial concept data and concept data after thermochemistry learning.

The validity test in this study used data triangulation. Data triangulation is checking data from various sources in various ways and times. The triangulation technique used in this research is a method triangulation technique in the form of concept data from the results of semi-structured tests and interviews, while the source triangulation is from the subject and the chemistry subject teacher. Data sources in this study include test results descriptions, interviews, documentation, attendance list, and grade grades for chemistry teachers.

Results and Discussion

The initial test results as initial concept data from 60 students of class XI IPA obtained an average value (mean) of 45 and a standard deviation of 8, so these results can be used as a reference in categorizing students' ability levels. Students who score ≥ 53 are included in the high category, students who get $37 < \text{score} < 53$ are included in the moderate ability category and those who score < 37 are included in the low ability category. So that the grouping of students based on the level of ability obtained, namely six students with high ability criteria, 48 students with moderate abilities, and six students with low abilities. The tabulation list of student categorization results based on the results of the initial test is presented in Table 1.

Table 1. Result of student ability grouping analysis

No.	Grouping of Student Acquired Values	Criteria	The number of students
1.	Value ≥ 53	Tall	6
2.	$37 < \text{Value} < 53$	Moderate	48
3.	Value < 37	Low	6
Total			60

The results of grouping students' abilities in the study from Table 1 are used to determine the research subjects. Students who are used as research

subjects are two students who are in high, medium, and low ability levels. The exact details of the research subjects can be seen in Table 2.

Table 2. Research subject

No.	Research Subject Code	Mark	Criteria Group
1.	HA1	64	High
2.	HA2	60	High
3.	MA1	50	Moderate
4.	MA2	48	Moderate
5.	LA1	35	Low
6.	LA2	28	Low

Conceptual changes were experienced by the six subjects in class XI science based on the study of the initial concept and the concept after learning. Conceptual change is a condition in which students hold the conceptions and beliefs that students have where both (conceptions and beliefs) conflict with what is being studied so that students decide to change them. Concepts in thermochemistry are represented by five descriptive questions consisting of the concept of the heat of reaction, reaction enthalpy on a calorimeter (CP1), Hess's law (CP2), and energy diagrams (CP3), and bond energies (CP4 and CP5). In the five concepts, almost all subjects experienced a conceptual change. The thermochemical conceptual changes for each subject, namely: (1) high-ability subjects (HA1 and HA2) occurred in the concept of the heat of reaction, reaction enthalpy in the calorimeter, and bond energy; (2) the subject of moderate ability SS1 occurs in the concept of the heat of reaction, reaction enthalpy in the calorimeter, Hess's law, and bond energy; and (3) the subject of low ability (LA1 and LA2) occurs in the concept of the heat of reaction, reaction enthalpy on the calorimeter, Hess's law, and bond energy. Subjects of high ability (HA1 and HA2) in solving the CP1 problem, namely the concept of reaction heat and reaction enthalpy, understood well the equation and how to solve the concept problem. Still, there was a conceptual change where the subject was mistaken in converting temperature units and determining the number of moles of substance formed in the initial concept.

In CP2 and CP3, the concept of Hess's law and the energy diagram, the subject understands well how to solve the problem of the concept. As for CP4 and CP5 on the concept of bond energy, the subject underwent a conceptual change. Namely, the subject understood how to solve the concept problem by using the bond equation well but was mistaken in determining the coefficients and speciations of the reactant-product and enthalpy formation related to the evaporation enthalpy in the initial concept. Medium capability subjects (MA1 and MA2) and low ability subjects (LA1 and LA2) understand CP2 and CP3 about Hess' Law concepts and energy diagrams so that they do not undergo conceptual changes. Whereas in CP1 (the concept

of reaction heat and enthalpy), CP4 and CP5 (the concept of bonding energy) undergo conceptual changes but at different stages of completion for each level of the subject's ability. The subject of ability is experiencing conceptual changes in determining temperature changes and the number of moles of substances formed in the reaction equation. Besides that determining the speciation of product-reactants on the reaction equation and the influence of coefficients on the enthalpy of reactions are subject to errors in the initial concept.

Meanwhile, the low ability subject understands the same concept as the medium ability. Still, the conceptual changes that occur are slightly different in solving the concept problem, including being mistaken in converting temperature units. And then determining the number of moles of product substances, and determining the speciation of reactants-products—not including coefficients in determining reaction enthalpy and not understanding the bond energy equation. Misconceptions occur on initial tests to define the concepts that each subject has. Each issue has a different understanding of each concept in thermochemistry; this is because the initial concepts in each subject are different from each other, so conceptual change is significant because there is a fact that students' ideas before being taught are contrary to scientific truth, especially in teaching science (Küçüközer & Kocakulah, 2008).

In addition, in the interview session, a statement was obtained from the subject that they did not understand the concept and did not even know it at the time of previous learning. However, a significant conceptual change occurred after the idea of thermochemistry was re-taught, especially in the subjects of medium and low abilities. The condition experienced by the issue is a condition where the subject is aware of a contradiction within himself. The subject's awareness of this conflict is the first step that is needed consciously to make changes (Jonassen et al., 2005; Jonassen & Ester, 2012). The subject also said that he always equates the old concept with the new concept he received. If appropriate, it will solve the problem with the concept, but if there is a difference, the subject uses a concept that is easier to understand and makes sense in his mind. Equating concepts is one of the characteristics of a conceptual change known as assimilation. Assimilation by Ijirana et al. (2021) is a step to match the old idea with the new concept accepted by the subject. Nadelson et al. (2018) also suggest that conceptual changes occur due to assimilation and accommodation, and accommodation occurs if the subject experiences: dissatisfaction (dissatisfaction), plausible new concepts (plausibility), clarity of new ideas (intelligibility), and benefits of new concepts (fruitfulness).

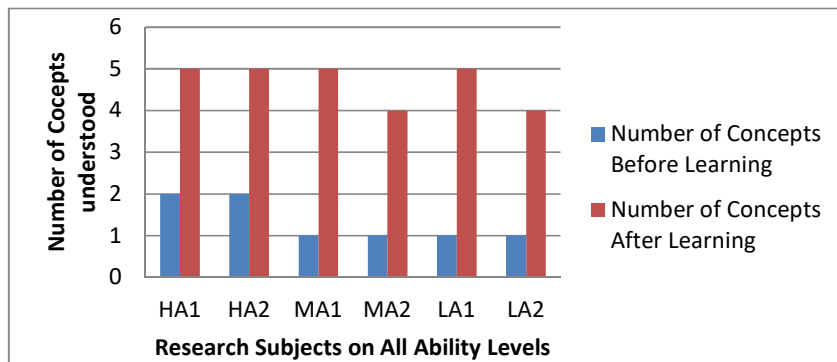


Figure 1. Comparison of subject conceptual changes at each ability level

Various conceptual change factors became the study's findings when interviews were conducted with the six subjects. The conceptual change factors include the ability of teachers to teach and the reduced intensity of meetings for chemistry lessons during the Covid-19 pandemic. The ability of teachers to master and deliver material is considered to significantly affect the quality and process of learning science in the classroom. When teaching thermochemical material, the teacher of class XI uses the presentation and assignment method, where students are divided into several groups and then given the task of presenting the thermochemical material. From the subject's statement, they experienced confusion when reviewing learning resources (books and sources

from the internet) and comparing them with those explained by the class teacher after the presentation. In addition, the time given is not commensurate with the amount of material each group has to present. Therefore, some concepts have not been able to be understood by students or unknown, such as the bond energy and the average bond energy. After the researcher carries out the thermochemistry learning, the model he uses can provide a conceptual change for the better. Baser (2006) revealed that developing strategies according to the conditions of conceptual change to create cognitive conflict in students, organizing instructions for diagnosing errors in students' thinking and helping students relate one concept to another can reduce conceptual change. Therefore, selecting strategies and

appropriate learning models is necessary for teaching chemistry.

Conclusions

Based on the results of research and discussion, it can be concluded the conceptual change occurs in all subjects of high ability (HA1 and HA2), subjects of medium ability (MA1 and MA2), as well as in subjects of low ability (LA1 and LA2). Conceptual changes that occur in high ability include completing the concept of reaction heat, changes in reaction enthalpy in the calorimeter device, and the idea of bond energy. The subject of medium ability SS1 undergoes a conceptual shift in the reaction heat, a change in the enthalpy of the reaction in the calorimeter apparatus, and the bond energy. In contrast, MA2 on the idea of bond energy undergoes a conceptual change in the negative direction. Subjects of low ability LA1 experience conceptual changes in reaction heat, changes in reaction enthalpy in the calorimeter apparatus, Hess's law, and bond energy, while LA2 undergoes conceptual changes in the negative direction of the bond energy concept.

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