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Development of Students' Conceptual Understanding through STEAM Project Integration in Thermochemistry

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Abstract

This study aims to develop students' conceptual understanding by integrating the Science, Technology, Engineering, Art, and Mathematics (STEAM) project in thermochemistry. The qualitative research was employed with interviews, reflective journals, observations, students' worksheets, and conceptual understanding tests on 40 students in senior high school. The STEAM project was implemented through a project-based learning model to develop students' understanding of exothermic and endothermic, combustion reactions, and enthalpy concepts. The STEAM project being developed is a steamship using three fuels: methanol, ethanol, and palm oil. The results showed that the student's understanding of enthalpy calculation had developed. Otherwise, the concept of exothermic, endothermic, and combustion reaction, especially related to applying the concept in daily life, is still undeveloped. Thus, some of the students experienced misconceptions. Therefore, the integration of contextual learning such as STEAM needs to be continuously applied to provide students with opportunities to develop their conceptual understanding and application in daily life.

Keywords: conceptual understanding, STEAM project, thermochemistry

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1. Introduction

Chemistry is a very theoretical discipline that includes various abstract concepts (Taber, 2019). According to Sirhan (2007), chemistry is conceptual, which require an understanding of concepts in a meaningful way. Conceptual understanding in chemistry is defined as reasoning various core chemical ideas, predicting and/or explaining chemical systems, critical reasoning in solving problems, and applying the core ideas of chemistry related to theories, patterns, relationships, and others into real conditions (Holme et al., 2015).

In chemistry learning, students often experience difficulties because of various factors. One of them is the abstract concept of chemistry, many terminologies difficult to understand, teacher-centered learning, and the inability to relate one concept with another concept or with relevant context (Woldeamanuel et al., 2014). Consequently, students are prone to experience misconception because they do not have a deep understanding of concepts.

One of popular concepts in chemistry learning, but considered difficult and often found misunderstanding concepts among students, is thermochemistry (Anderson et al., 2005). Thermochemistry is a fundamental concept in science and important in everyday life (Chen et al., 2017). Although, thermochemistry topics consists of various fundamental concepts such as heat, temperature, enthalpy, and energy change. Thermochemistry holds an important role in understanding all chemistry phenomena, making it very popular and challenging for students (Krummel et al., 2007). The main challenge for students is the concepts abstraction level in thermochemistry (Mulop et al., 2012). Numerous research in conceptual with chemistry topics reveal that students experience many problems in thermochemistry. One of them is the students' inability to distinguish the conceptsof heat and temperature. These students assume "heat" and "temperature" have the same meaning and used them interchangeably (Niaz, 2006). Moreover, to learn thermochemistry, students must have good initial knowledge of mathematics and stoichiometry (Zakiyah et al., 2018).

Based on the problems mentioned above, a learning approach that can improve students' conceptual understanding and its application is needed. Science, Technology, Engineering, Art, and Mathematics (STEAM) is a learning approach rooted in constructivism theory that places students at the center of learning (Gross & Gross, 2016). STEAM provides opportunities for students to apply their knowledge from various disciplines to solve problems in real life through project creation (English, 2016). The integration of STEAM in learning encourages students to improve their understanding of the concepts they learn through appropriate contexts (Guzey et al., 2017). Various previous research has shown that STEAM is an approach that encourages the creation of a student-centered learning environment which have various positive effects on the development of students' literacy (Adriyawati et al., 2020; Rahmawati et al., 2020), critical thinking skills (Rahmawati et al., 2020), conceptual understanding and reduces student misconceptions (Ozkan & Topsakal, 2020). Therefore, this research aims to develop students' conceptual understanding of thermochemical topics through the integration of STEAM projects with relevant contexts.

2. Research Method

The methodology used in this research is qualitative research to fully and deeply describe the students' understanding of concepts that can develop during learning activities with the integration of the STEAM project on thermochemistry.

2.1. Research Design

This research involved 40 students (14 boys and 26 girls) in 11th-grade natural science in one of the public schools in Banten Province. Although the characteristics of students in this study are known based on observations and teacher interviews that show students have varied cognitive abilities, it can be seen from the chemistry score from the odd semester that students have high, medium and low scores.

The research was conducted in three steps: the planning, implementation, and final steps. First, a thermochemical analysis was carried out at the planning step, a literature analysis on the STEAM-based PjBL approach, compiling research instruments such as worksheets, reflective journals, interview guidelines, observations, and test instruments, and compiling a lesson plan. Next, according to the lesson plan, the implementation phase is carried out, makes observations, interviews, provides reflective journals, and tests understanding of thermochemical concepts. Finally, STEAM integration learning in PjBL on thermochemistry is carried out in six steps, as shown in Figure 1.

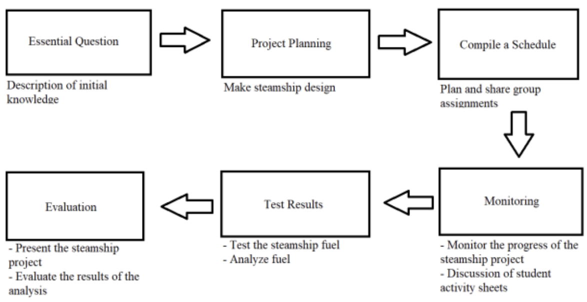


Figure 1. STEAM-PjBL Learning Steps

The project being developed is a steamship that has been adapted to the concept of thermochemical material. Steamship STEAM project design can be seen in Figure 2.

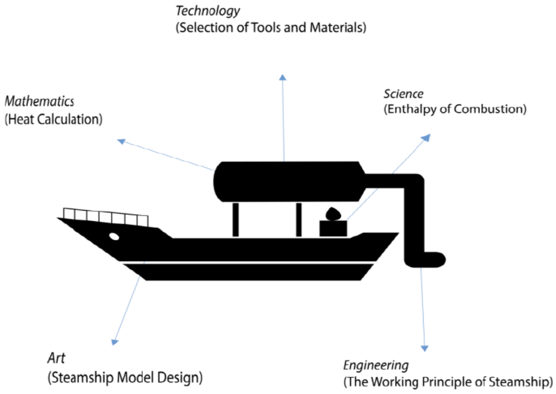


Figure 2. Steamship STEAM Project Design

The steamship project was developed using three fuels, namely methanol, ethanol, and vegetable oil. The criteria for a good steamship include the presence of a chimney to remove the combustion products, a combustion chamber, a place for fuel, the bow (the front of the ship) and the stern (the back of the ship).

The final step of the research includes processing data obtained during the study, analyzing data, and drawing conclusions.

2.2. Data Collection Technique
Data collection consists of several techniques, namely interviews, observations, student activity sheets, reflective journals, and tests of understanding the concept of thermochemistry.

2.2.1. Interview
Researchers conducted semi-structured interviews related to understanding the concepts that students felt were developing and to find out students' responses about STEAM project learning activities. In addition, interviews were conducted individually with 22 students focused on implementing and understanding students' concepts.

2.2.2. Observation
Observations were made by two observers using an open observation sheet. Observations were made by recording or recording various activities carried out by the subject during the study to observe the development of students' understanding of thermochemical concepts during the learning process.

2.2.3. Reflective Journal
Students write reflections on chemistry learning with the integration of the STEAM project after the learning activity ends at each meeting. In each meeting, students are given different questions every day that contain the challenges faced by students and student involvement in learning at each meeting. Examples of reflective journals given are as follows.

"How do you reflect on learning using the STEAM project approach that has been carried out. Give your reasons in full! "

2.2.4. Student Activity Sheet
Student activity sheets are used to help students develop their understanding of each learning topic. So that later, it will not only be at the end of the learning session but also at the learning process.

2.2.5. Concept Understanding Test
The test is carried out at the end of the learning session to analyze students' conceptual understanding during the learning process. Three thermochemical concepts are being tested, namely exothermic and endothermic, combustion reactions, and enthalpy calculations. The examples of questions given are as follows.

A student wants to do steamship trials using one mole of methane (CH_4) and one mole of butane (C_3H_8) as fuel. What fuel do you think caused the steamship to go the farthest? Explain in detail! Prove it by calculation! If known:

$$\Delta H_f{}^o\ CH_4 = -74{,}87\ kJ\ mol^{-1}$$
$$\Delta H_f{}^o\ C_3H_8 = -104{,}7\ kJ\ mol^{-1}$$
$$\Delta H_f{}^o\ CO_2 = -393{,}5\ kJ\ mol^{-1}$$
$$\Delta H_f{}^o\ H_2O = -285{,}8\ kJ\ mol^{-1}$$

2.3. Data Analysis Technique
Analysis was carried out in three steps; reduction, data presentation, and concluding

(Miles & Huberman, 1984). At the data reduction step, the selection, grouping and centralizing of interview data, observation, reflective journal, and concept understanding tests are carried out, as well as removing unnecessary data and organizing data according to the three concepts analyzed, namely exothermic and endothermic, combustion reactions, and enthalpy calculations.

The data that has been reduced is then presented in the form of narrative text, descriptive text, and graphics to make it easier for researchers to analyze the development of students' concepts. The final data analysis step is drawing conclusions that need to be verified to verify their accuracy, consistency, and compatibility with other data.

2.4. Data Validity Technique

The data validity technique uses the trustworthiness test. Trustworthiness is a valid, reliable, and objective qualitative research criterion. The criteria used in this research are the credibility test (Guba & Lincoln, 1989) including: a) prolonged engagement, the researcher acts as a teacher during the research process to find things that the observer does not observe. b) persistent observation, the researcher and two observers conducted continuous data collection to focus on the development of students' conceptual understanding. The data were collected in the form of a systematic description, and the researcher double-checked the data. c) progressive subjectivity, monitoring of the development of students' conceptual understanding is carried out by researchers with the assistance of two other observers. And d) member checking, the researcher reconfirms the data obtained to students so that there are no errors in interpreting the data.

3. Result and Discussion

3.1. STEAM Project Integration in Project-Based Learning

STEAM project integration in project-based learning will not only make students learn basic theory in project completion techniques, but students will also learn problem-solving skills, critical thinking, and collaboration skills. Project-based learning in chemistry learning involves students in authentic situations to explore and apply chemistry topics in complex problems and are relevant to the practice they are preparing (Chiang & Lee, 2016). The construction of the steamship project is carried out in groups through the following learning steps.

3.1.1. Essential Question

The essential questions referred to in this study are questions that explore students' knowledge. The purpose of giving essential questions is to find out the students' initial knowledge. The following are examples of students' answers to essential questions regarding the meaning of thermochemistry, exotherm and endotherm.

"Thermo can be interpreted as heat, so thermochemistry is the science of chemistry that deals with heat"
(Observer 1, Field Notes, 19 October 2018)

"Exotherm is a reaction that produces heat while endotherm produces cold"
(Observer 2, Field Notes, 19 October 2018)

The results of above observations indicate that students already have initial knowledge of the concept of thermochemistry, although they are not yet in-depth. Initial knowledge is all knowledge or information that students have through the assimilation of experiences in everyday life. Therefore, the activation of students' initial knowledge becomes an important stage in learning to reflect the amount of relevant knowledge that students may already have to bring into learning situations (Hattan & Alexander, 2020).

3.1.2. Project Planning

This planning step is the step where students make a steamship design. Students are given the freedom to make designs and choose materials for their steamships. In designing, students have been able to independently find information regarding the shape of a simple steamship, making it, working principles, and other related information.

"I am looking for information on the web and youtube about steamship image and how it works"
(Students 16, Interview, 19 October 2018)

The interview results above show that the STEAM project integration in PjBL encourages students to build basic skills to seek information, which is the core of the learning process (Papathanasiou et al., 2014). Figure 3 shows some of the steamship designs which the students have made.

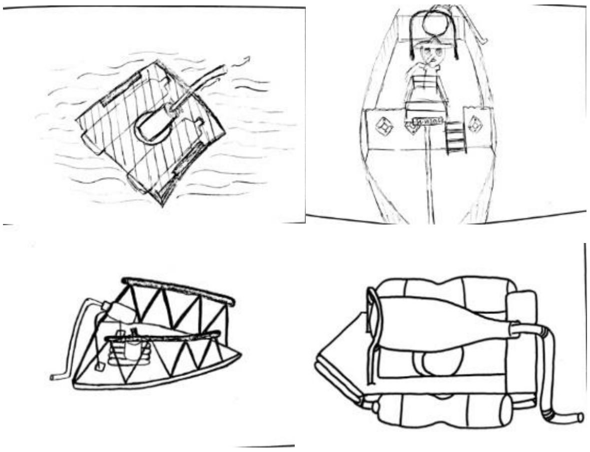


Figure 3. Steamship Design

As shown in Figure 3, each group made a different design according to the criteria for a good steamship, namely having a front, a rear, a fuel container, a combustion chamber, and a chimney.

"I want to make a steamship that is big enough to be balanced. I use styrofoam for the hull so that the ship can float, the hull is coated with aluminum so that the ship doesn't melt and catch fire"
(Student Interview, 19 October 2018)

The interview above shows that students can connect various ideas by paying attention to equilibrium, buoyancy, and types of flammable materials. This is consistent with the research of Glancy and Moore (2014), which states that STEAM encourages students to connect various ideas and is closely related to conceptual understanding. In addition, students also show creative thinking by making different steamboat designs and using various materials. These results are consistent with the research of Lou et al. (2017), which states that the STEAM project can develop creativity, including adventure, curiosity, imagination, and challenges.

3.1.3. Schedule Arrangement

At this step, students set the schedule for making steamships and divide tasks into groups. This step shows if students can design steamship building activities and share existing tasks evenly and independently so that cooperation is well established between group members. Arranging this schedule requires good communication and collaboration between group members. This is reinforced by the research of Oner et al. (2016), which states that project-based learning can invite students to collaborate, communicate among students, solve problems, and carry out independent learning.

3.1.4. Monitoring

At this step, the teacher monitors the progress of student work. Figure 4 shows the results of steamship project made by students.

Figure 4. Results of Steamship Project

The steamship that has been made considers various aspects, such as the ship's weight and the balance of the ship. In addition, the discipline of art is evident in ship design as various colors are used to decorate steamships.

After that, students can discuss the steamship project and answer some of the questions on the student activity sheet. Group discussions make students active in learning, because students can share the concepts they understand. In addition, their understanding of the concept of thermochemistry will influence the results of the group analysis.

"The working principle of a steamship is the law of action-reaction (Newton II's law). The steamship also uses Newton's concept of law III. The steamship's engine exerts a force of action by spraying gas out of the ship's back, and the gas exerts a reaction force by pushing the ship forward. $F_{action} = -F_{reaction}$. Heat transfer in steamships is a type of heat transfer by convection"
(Student, Interview, 5 November 2018)

Students can connect the concepts of chemistry and physics with the working principles of a steamship. This shows that students' understanding of the concept seems to have increased. This statement is following research by McDonald (2016) that mastery of scientific disciplines will make students able to connect knowledge to other disciplines, such as chemistry and physics.

3.1.5. Test Results

In this step, fuels are testing, which are ethanol, methanol, and palm oil. This test is carried out to determine the effectiveness of three fuels, which can cause the steamship to travel fast and far. Understanding the concept of heat, combustion reactions and enthalpy calculations will be seen at this step. The results of the six groups were different.

"The ethanol fuel will cause the steamship to go fast and far because the fire is large so that the water boils quickly and then the steam is generated a lot, the ship moves fast"
(Student 1, Reflective Journal, 5 November 2018)
"What makes ships move faster is methanol because the combustion process is faster and bigger"
(Student 16, Reflective Journal, 5 November 2018)

The above statement shows students have different results, and each group has a strong enough reason. This indicates that students can think critically. This is consistent with Larmer and Mergendoller (2010) research, which states the challenges of developing projects and linking them to the basic principles of STEAM have encouraged students to develop creativity and critical thinking. This is also in line with research conducted by Hadinugrahaningsih et al. (2017), which states that STEAM integration can be implemented to develop critical thinking, communication, motivation, creativity, respect, discipline, collaboration, responsibility, adaptation, and leadership, as well as information and media literacy.

3.1.6. Evaluation

Students present the work of their steamship, several groups argue about differences in the results of the fuel trials with references. If a group has a strong understanding of the concept of thermochemistry regarding the reasons for the fuel test results, it will be easy to defend its opinion. Students are allowed to present the results of their analysis using PowerPoint media and posters to other groups, as illustrated in the conversation below.

Student 1: Why are your group's results different from the reference, should the ship run faster when using palm oil > methanol > ethanol?
Group 3: The results of our group fuel trials show that ethanol causes steamships to run fast and far. In our opinion, this is because the combustion process in ethanol is faster than palm oil, so that it produces a lot of steam.
Student 3: Our fuel test results are also not following the reference, but methanol is the fastest running steamships compared to palm oil. Our reason is that the concentration of palm oil (oleic acid) is 43%, and the rest is another substance that is not the main ingredient of palm oil, whereas the methanol concentration was 93%. Because methanol content is more than

palm oil, methanol produces more heat which causes steamships to run fast.
(Observer 1, Field Notes, 19 November 2018)

The conversation shows that students can evaluate the results of their projects and compare them with the results of other groups. At this step, students evaluate their understanding of thermochemistry concepts, especially when misunderstandings occur, and at this step, there is a change in understanding of the concept by students.

The discussion of the project results is expected to develop students' conceptual understanding because it is influenced by students' knowledge and experience through interaction with the environment and utilizing previous knowledge. This aligns with Sholikhan (2017) statement that intellectual ability develops when a person faces a new confusing experience. When they try to solve problems caused by experience, they connects new knowledge with previous knowledge and constructs new meanings.

3.2. Development of Students' Conceptual Understanding on Themochemistry Topics

Students' understanding of the concept of thermochemistry through the STEAM project only focuses on exotherms & endotherms, combustion reactions and enthalpy calculations.

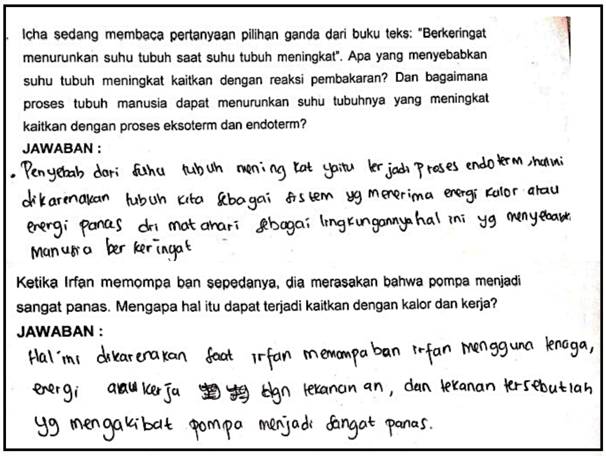
3.2.1. Exothermic and Endothermic Concept

Based on the analysis of students' prior knowledge, it is known that students distinguish exothermic and endothermic only in producing heat or cold. The integration of the STEAM project in thermochemistry learning helps students develop conceptual understanding, as seen in the following observations.

"The teacher gave a video about a snow doll suddenly melting when exposed to the sun and asked the question, why did this happen? One of the students answered that because the snowman absorbs heat/heat from the sun causing the temperature of the snowman to drop and melts, the process is called endothermic"
(Observer 2, Field Notes, 19 October 2018)

This statement illustrates that students have been able to understand the endothermic concept by explaining in detail that processes occur in a snowman. This is consistent with the research of Yakman and Lee (2012), which states that learning with STEAM integration refers to constructivist learning theory in which students will actively build their knowledge through enjoyable learning experiences.

Next is a question that discusses the concept of exothermic and endothermic and their relation to phenomena in everyday life. The test results showed that most of the students' answers lacked detail, and there were misconceptions.


Icha sedang membaca pertanyaan pilihan ganda dari buku teks: "Berkeringat menurunkan suhu tubuh saat suhu tubuh meningkat". Apa yang menyebabkan suhu tubuh meningkat kaitkan dengan reaksi pembakaran? Dan bagaimana proses tubuh manusia dapat menurunkan suhu tubuhnya yang meningkat kaitkan dengan proses eksoterm dan endoterm?

JAWABAN :

• Penyebab dari suhu tubuh meningkat yaitu terjadi proses endoterm, hal ini dikarenakan tubuh kita sebagai sistem yg menerima energi kalor atau energi panas dri matahari sebagai lingkungannya hal ini yg menyebabk manusia berkeringat

Ketika Irfan memompa ban sepedanya, dia merasakan bahwa pompa menjadi sangat panas. Mengapa hal itu dapat terjadi kaitkan dengan kalor dan kerja?

JAWABAN :

Hal ini dikarenakan saat irfan memompa ban irfan menggunakan tenaga, energi atau kerja dgn tekanan an, dan tekanan tersebutlah yg mengakibat pompa menjadi sangat panas.

Figure 5. Concept Understanding Test Results

The problems presented in Figure 5 are related to the concept of exothermic and endothermic in everyday life. Although exothermic and endothermic are basic knowledge for studying thermochemical material, students need to know the exact definition of exothermic and endothermic to answer this question.

The students' answers in Figure 5 show that students are still unable to connect chemical concepts with daily life. This is because so far the process of learning chemistry rarely involves examples and applications in everyday life. According to Childs et al. (2015), there are various ways of relating chemistry to everyday life. Such as topical events appearing in the news media and discussions; many of these topics are about the environment, energy, and resources, and all involve science/chemistry or conducting experiments to prove content in food or beverage products.

Next is a question to determine the system/environment as well as exothermic and endothermic. For example, the problem concept in Figure 6 relates to the system/environment and exothermic and endothermic.

> Solid Ammonium Chloride is reacted with a solution of Barium Hydroxide in a beaker. In this experiment the thermometer showed a decrease in solution temperature from 25ºC to 12ºC. Based on the illustrations given:
>
> a. Show which one is the system and environment!
> b. Check if the reaction is exothermic or endothermic!

Figure 6. Problems Example

Students should know the definition in advance of the system/environment as well as exothermic and endothermic.

"In this case, the chemical reaction (ammonium chloride and barium hydroxide) is a system, and the beaker is an environment. The reaction is exothermic because the system releases heat to the environment."
(Student 6, Interview, 23 November 2018)

Analysis results of students' answers to the questions in point a of Figure 6 show that all students can determine which ones belong to the system and environment. Thus, the understanding of the concept of systems and the environment has been mastered well by students. The research of Greenbowe and Meltzer (2003) also shows the same results in their studies, 22% (of n= 207) correctly identified chemical reactions as systems while only 6% correctly identified the environment. Whereas in point b (Figure 6), some students still answered incorrectly that the reaction was exothermic. This was confirmed by Ayyildiz and Tarhan (2018) that it turned out that students tended to experience difficulties in understanding and distinguishing between exothermic and endothermic reactions. Therefore, understanding the concept of exothermic and endothermic was needed to be improved, because exothermic and endothermic concepts are the basis of thermochemistry topic.

3.2.2. Combustion Reaction Concept

The following concept questions discuss how students can predict the death of seven young people in a house. It takes knowledge about the difference between the perfect and incomplete combustion reaction by students to answer these questions.

> 1. The following is one reaction that takes place while the room heater is running. Complete the following reactions!
> $CH_4(g)$ + ……. → ……. + $2H_2O(g)$
>
> 2. When the amount of oxygen is insufficient, the methane oxidation reaction cannot fully proceed and the formation of CO gas occurs, this gas can poison the people around the heater with the chimney if the concentration in the air exceeds the tolerable threshold value. Explain the reason for the death of 7 young men! (there is a heater with a chimney in the house of the seven people).

Figure 7. Problem Examples of Combustion Reaction Concept

The students' answers to the questions in point 1 of Figure 7 show that almost half of the students answered correctly for the above reactions. Only a few students responded to the question wrong. The following are the results of the student interview who answered the question incorrectly.

Teacher: Why did you answer the reaction with $CH_4 + CO_2 \rightarrow C_2 + 2\ H_2O$
Student: I still don't know how to make the right reaction.
Teacher: Did you know that this question is an example of a combustion reaction?
Student: I don't know if it's a combustion reaction

Teacher: What do you know about the combustion reaction?
Student: The combustion reaction is a reaction that causes damage or loss of a substance/object.
(Student 21, Interview, 23 November 2018)

These results indicate that students do not understand the concept of the combustion reaction. Oxidation and combustion in chemistry is a material that often becomes a problem, especially when oxidation and combustion are closely related to everyday life experiences. Daily life experiences are usually the main source of explanation and alternative conceptions among students (Eilks et al., 2007). Interpretation of everyday phenomena usually gives rise to alternative conceptions in which students believe that all chemical reactions are irreversible, that combustion is usually associated with the destruction or loss of matter and mass, or that combustion always produces gaseous compounds (Nakhleh, 1992).

In question 2 (Figure 7), only a few students could answer this question accurately and in detail. Here are the answers of the students.

"In my opinion, it seems that there is damage to the heating in the house so that the products of the combustion reaction enter the house instead of going out. This causes the oxygen concentration in the house to decrease because what is produced from incomplete combustion is carbon monoxide which is very dangerous for the body. Then carbon monoxide will bind to hemoglobin and cause death. The bond between carbon monoxide and hemoglobin is stronger than the bond between oxygen and hemoglobin"
(Student 16, Interview, 23 November 2018)

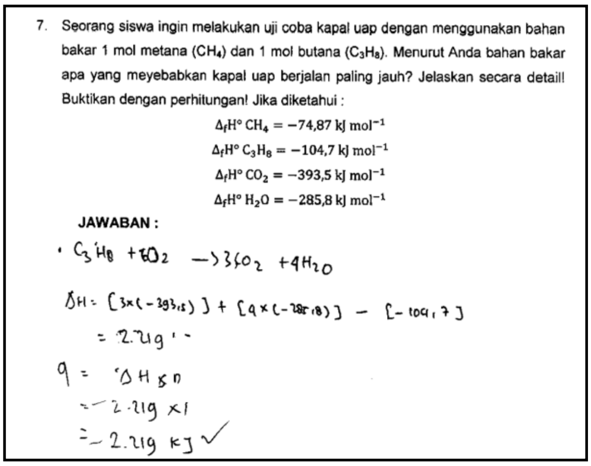
The answer above shows that students can answer the deaths of seven young people due to inhalation of carbon monoxide from incomplete combustion. Besides, they can relate it to the concept of biology, namely, if someone inhales too much carbon monoxide, the hemoglobin will bind carbon monoxide more strongly than oxygen, so that it will cause death. A good understanding of the concept of the combustion reaction concept with the concept of body metabolism will make students combine their knowledge to answer the question. But there are students who only answer chemical concepts, such as the results of the following interview.

"The heater uses methane fuel so that the result of combustion produces more carbon monoxide, the heating in the house seems to have a problem so that carbon monoxide enters the house and causes the amount of oxygen to decrease so that the seven young men inhaled it and died"
(Student 10, Interview, 23 November 2018)

Only a few students answered questions in point b of Figure 7 accurately and in detail. In contrast, some students answered that they were limited to inhaling carbon monoxide without clearly explaining the concept of biology. These results indicate that the students' understanding of concepts has not been too developed, especially concepts related to everyday life. On the other hand, Fensham (2009) research shows that contextual-based teaching leads to more student involvement in science concepts. One example of contextual-based teaching is to apply the STEAM approach. This is because STEAM can be integrated into chemistry learning in real-life problems in the Indonesian context (Rahmawati et al., 2019).

3.2.3. Enthalpy Calculation Concept

Understanding the concept of enthalpy calculation can be seen in the students' test answers. The test results showed that most of the students were able to answer the enthalpy calculation questions. The following is an example of an enthalpy calculation concept problem.


7. Seorang siswa ingin melakukan uji coba kapal uap dengan menggunakan bahan bakar 1 mol metana (CH_4) dan 1 mol butana (C_3H_8). Menurut Anda bahan bakar apa yang meyebabkan kapal uap berjalan paling jauh? Jelaskan secara detail! Buktikan dengan perhitungan! Jika diketahui :

$\Delta_f H^\circ\ CH_4 = -74{,}87\ kJ\ mol^{-1}$

$\Delta_f H^\circ\ C_3H_8 = -104{,}7\ kJ\ mol^{-1}$

$\Delta_f H^\circ\ CO_2 = -393{,}5\ kJ\ mol^{-1}$

$\Delta_f H^\circ\ H_2O = -285{,}8\ kJ\ mol^{-1}$

JAWABAN :

Figure 8. Test Results of Understanding the Concept of Enthalpy Calculation

The concept in the problem shown in Figure 8 is the enthalpy calculation. Therefore, this problem answer with the understanding of the concept of enthalpy formation and combustion reactions. The entalpy reaction calculation is necessary to know the value of enthalpy formation for each compound present in the combustion reaction.

Yuriev et al. (2017) stated that students often experience difficulties caused by various factors in solving problems in chemistry. These factors include low concept knowledge, misconceptions, and bad problem-solving strategies such as applying algorithms that are only memorized without understanding the suitability of their use in learning concept. Yuriev et al. (2017) also stated that students' problem solving process is influenced by various aspects such as cognitive, motivation, and behavior. Cognitive factors include content knowledge, conceptual understanding, and process skills.

The results in Figure 8 show that the understanding of enthalpy calculation concept has developed because students can make the combustion reaction correctly so that the enthalpy calculation results are correct. Furthermore, this shows that students already understand various related terminologies to solve the problems given (Yuriev et al., 2016).

4. Conclusion

Based on the results of research and discussion, it can be concluded that the integration of the STEAM project in thermochemical learning has been able to develop students' understanding of enthalpy calculation concepts through various problem-solving activities. Meanwhile, understanding the concept of exothermic and endothermic and combustion reactions still needs to be developed. Students still have difficulty distinguishing exothermic and endothermic, making combustion reaction equations, and students have not been able to connect chemical concepts with everyday life. This difficulty is seen in students' answers which tend not to be detailed, and there are some misconceptions. Nevertheless, exothermic and endothermic and combustion reactions are basic concept in studying thermochemistry. So it is necessary to apply STEAM in schools continuously. This is because STEAM learning can improve students' understanding of concepts and is contextual (Bahrum et al., 2017).

Various challenges in this research include time management, which must be adjusted to the academic calendar, student involvement, and STEAM project ideas following the subject's concept. In addition to the development of students' understanding of enthalpy calculation concept, other findings obtained from the application of STEAM in project-based learning are developing creativity, collaboration, information literacy, and producing meaningful learning that increases student motivation and involvement in learning.

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