IDENTIFICATION OF CRITICAL THINKING CAPABILITIES OF HIGH SCHOOL STUDENTS USING THE INTEGRATED PHYSICS MODULE OF ENGINEERING DESIGN PROCESS (EDP)

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Abstract

The Indonesian curriculum states that science education is one of the efforts to improve the quality of people's lives to be able to have knowledge and skills in solving problems. Problem solving skills require capable critical thinking skills to be able to analyze, assess and reconstruct the knowledge they have to solve problems. In addition, the ability to think critically is an important aspect that must be developed according to the competence of 21st century skills. This research is a type of qualitative research with a case study approach to identify students' critical thinking skills using the Engineering design process (EDP) integrated physics module which is differentiated by gender. The subjects of this study were six students, each consisting of three male students and three female students in class XI MIPA 2 at MAN 1 Jember. The data collected in the form of observation data, documentation and interviews. The data collected will be reduced, analyzed based on indicators of critical thinking skills and presented to then draw conclusions. All data obtained will be tested for validity using triangulation techniques. The results of the identification of critical thinking skills indicate that there are differences in the characteristics of the proble solving process between male and female students. Female students are better at interpreting problems accurately and in detail than male students. Meanwhile, male students dominate in giving ideas and even though some ideas are not quite in accordance with the concepts of physics and are still in doubt. Overall, there is no significant difference between the critical thinking abilities of male and female students. All students tend to still not fully understand the physics concepts related to solutions, so that the statements and opinions given regarding solutions tend to be less clear and less logical.

Keywords: *Critical thinking, Engineering design process, Gender*

1. INTRODUCTION

Physics as part of science is a natural science that explains observable phenomena with models. These models are based on human experience, rational thought, and detailed experiments (Suwindra, 2012). The process of understanding the concept of physics can be achieved if it starts with giving problems (Kurniawati, 2019). This will stimulate students to think deeply about what is being studied.

The Indonesian curriculum states that science education is used as a comprehensive effort to improve the quality of people's lives so that they are able to have knowledge and skills in solving problems (Syukri, 2018). The fact is that the physics learning process has not maximized students' problem solving abilities. This is shown by Lim's research in (Syukri, 2018) that students are generally aware that science is a difficult subject when students are asked to solve problems. Although many students said that they understood science concepts, they faced difficulties when asked to solve problems in science. Another study by Damopoli, et al. (2018) shows that there are still many teachers who have not provided full opportunities for students to use science process skills in solving problems, so students tend to easily forget concepts that have been studied previously. Science learning that involves predicting activities, linking variables, and analyzing the relationship between material and everyday life has not yet been created (Fitriani, et al., 2017).

The process of solving this problem is closely related to the ability to think critically. Scriven and Paul (2013) explain that critical thinking skills are important competencies to be developed because they can improve the ability to analyze, assess, and reconstruct what is in the mind to solve problems. This critical thinking ability in addition to developing along with physical development but also must be trained through the provision

of a stimulus that requires a person to think critically (Wahyuni, 2011). This critical thinking ability will help to find an alternative solution to the problem.

Science, Technology, Engineering and Mathematics (STEM) is one of the learning designs that can stimulate problem-based learning. According to Krajcik (2017) STEM greatly affects human life. In addition, the careers that will be available at this time mostly require practical STEM knowledge, ability to collaborate, solve problems, make decisions and innovate. Therefore, education needs to prepare learning that is able to develop these abilities for students as a form of preparation for students to plunge into real life.

What is important in STEM education is design. Design is an ability that enables students to clearly identify problems, examine what is known about the problem, generate solutions, develop prototype designs to demonstrate and share and receive feedback from other students regarding the design of the solution (Kracjik, 2017). An understanding of the design process is a key component in STEM education to build content knowledge and build solution engineering skills. The skill of engineering a solution is an important part of design knowledge and creating a product in solving problems. This engineering process is designed based on limitations (Moore, 2014). The existence of these limitations will make students think deeply to find effective solutions as needed. This makes students become a designer or engineer.

The integrated learning of the Engineering Design Process will be packaged in a teaching material, namely a module. The module was chosen because of its characteristics which are systematically arranged in simple language so that it is easy for students to understand according to their level of knowledge. The module is designed so that students are able to learn independently with minimal guidance from the teacher (Prastowo, 2014). So far, the packaging of physics in teaching materials still tends to present concepts, principles, examples of questions, and practice questions. The teaching materials that have been used so far have not been associated with real problems in everyday life (Sujanem, 2009). Another study by Lestari (2016) also shows the same thing, namely the packaging of physics in the teaching materials of the module only contains a summary of the material, formulas, sample questions, practice questions and slightly mentions phenomena in everyday life. Therefore, the module in the research is packaged with thepattern Engineering Design Process and relates it to everyday problems.

Previous research by Syukri (2018) showed that the results of the Independent sample T-test analysis had a significant difference in the average score of problem solving skills between students and the experimental group using theintegrated module Engineering Design Process and the control class group using the conventional module. Furthermore, in another study conducted by Altan (2018), science teaching conducted with Design Behavior Learning *was* STEM-basedable to improve students' decision-making skills in choosing a solution in the problem-solving process associated with real life. Other research related to STEM using the stages of the Engineering Design Process shows that the learning carried out is able to make students actively plan, exchange ideas, design, and re-evaluate the chosen solution system to be more effective. Another influence makes students develop 21st century skill competencies, namely creative, collaborative, critical, and communicative (Oanh, 2018).

In addition, the development of critical thinking skills is influenced by gender (Cahyono, 2017). When faced with problem-solving-based questions, male students and female students have different problem-solving tendencies (Nur, 2018). Other reports also show that the fields of technology and engineering are dominated by men, while women are mostly in the fields of biology or science (Hango, 2013). This is a challenge for educators to achieve gender equality in STEM so that male and female students can compete in STEM careers in the future.

Based on the description above, the formulation of the problem raised by the researcher is "How are the results of identifying high school students' critical thinking skills using the integrated physics module Engineering Design Process (EDP)"

2. RESEARCH METHOD

type of research is a qualitative research with a case study approach regarding high school students' critical thinking skills. by using the integrated physics module Engineering Design Process designed inactivities small group discussion. The EDP pattern used in this study uses the stages developed by Jolly (2015), namely asking students to start identifying problems,, imagine which is the process of reconstructing ideas to create a solution description, plan choosing a solution to be designed and implemented in the form of a design, create making a design based on supporting andscience data improving assess the effectiveness of the design and revise the design if it is judged to be less effective. The research site was conducted at MAN 1 Jember involving six students, each consisting of three male students and three female students.

The research design used in this research is the design of case study has been developed by Yin (2018) which consists of the plan, desaign, prepare, collect, analyze and share. At the initial stage, the researcher determines the problem to be studied then makes a research process design, determines the object and place of research. In addition, it also designed various instruments needed to collect data in this case in the form of modules and interview guidelines.

At the implementation stage, it consists of several meetings containing learning activities one to three in the module. Students will work on the available tasks in learning activities one to three individually related to the integrated physics learning Engineering Design Process. At the end of the activity, students will work on an evaluation task in groups consisting of one male student and one female student to solve a problem phenomenon using the pattern Engineering Design Process.

During the process of collecting data, the researcher observed the overall learning process and recorded student activities during the discussion process. The data is used to identify critical thinking skills. The critical thinking indicators used are critical thinking indicators proposed by Facione (2015) in table 1. below:

Table 1. Critical Thinking

Indicators Indicator	Description Indicators
Interpretation	Ability to understand and describe the meaning of experiences, situations, data, events, judgments, rules, rules, procedures and criteria
Analysis	Ability to identify relationships between statements, questions, concepts, descriptions to express beliefs, judgments, experiences, reasons, information and opinions
Evaluation	Ability to judge the credibility of statements or other representations about people's perceptions, experiences, assessment, to assess the logical relationship between statements, descriptions and questions
Inference	Ability to identify and determine the elements needed to draw logical conclusions

Other data needed are interviews conducted at the end of learning activities for each student. The type of interview used is a semi-structured interview with anquestion type open-ended. This interview was chosen because it was used to obtain in-depth information about students' critical thinking skills using theintegrated module Engineering Design Process.

The results of students' assignments will be analyzed which consists of stages of data reduction, data analysis, describing the results of data reduction and drawing conclusions. Then the results of the interview data in the form of audio will be transcribed using the initial code, namely O (observer), L (male students) and P (female students). The transcript data will be reduced, analyzed based on indicators of critical thinking skills, then presented to draw conclusions.

The use of several different data collection techniques ranging from observations during the learning process, the results of student assignments, documentation and interviews were used to measure the validity or validity of the data which was referred to as technical triangulation.

3. RESULT AND DISCUSSION

Identification of students' critical thinking skills was analyzed based on the

tasks that have been done either individually or in groups in the physics module with thelearning pattern Engineering Design Process which was then confirmed through an interview process to all students. The identification of critical thinking skills is viewed from critical thinking indicators, namely interpretation, analysis, evaluation and inference which are analyzed based on gender differences between male students and female students.

1. Individuals

In the early stages students work on assignments individually. This individual task is carried out in accordance with the EDP stages, but only partially, namely *ask*, imagine and plan as an exercise in using the EDP pattern. All students' answers will be categorized in high or low critical thinking skills according to the category rubric that has been made. Answers are selected based on the two best answers and the two lowest answers from each category.

a. Ask

The critical thinking indicator used at this stage is an interpretation indicator. At this stage it consists of several questions that invite students to describe the problem that occurs, why the problem occurs, what is needed to solve the problem and what physics concepts underlie the problem. Based on critical thinking indicators, answers in the high category are dominated by women and the low categories are mostly reflected in the answers of male students. Examples of student answers are as follows:

> [P3] : "Mother Sarah's pot does not conduct heat well. Mrs. Sarah wants a pot that conducts heat well but is not too expensive"
>
> [L3] :"Ms. Sarah has a problem with her pot."

At this stage the female students had better problem interpretation skills than the male students. Female students are able to interpret problems correctly and are also able to write them clearly and in detail. Meanwhile, men tend to write briefly and not accurately describe the problem at hand. This is in accordance with the research of Wijaya, et al (2016) which stated that male students tend to be inaccurate or inaccurate in describing problems in writing. This is consistent with the statement of Elliot, et al in Sari (2016) states that female students are more accurate and detailed in verbal skills, while boys are more critical in various interpretations

b. Imagine

At this stage students begin to create images of solutions tailored to the needs of problems based on previously acquired knowledge. The critical thinking indicator used at this stage is analysis. The results showed that there was one female student and one male student with a high answer category and one female student and one male student with a low answer category. Examples of student answers are as follows:

> [P1] : "Aluminum because of its high conductivity compared to others, namely 200 W/m℃ and plastic which has the ability to inhibit heat"
>
> [L2] : "Aluminum is a good conductor of electricity"

This indicates that female students and male students have the same ability when analyzing the relationship between statements and concepts to give an assessment to get an image of the right solution.

c. Plan

At thestage,stage plan students begin to plan a solution design design based on the description of the solution selected in the previous. Critical thinking indicators at this stage are also analytical skills to link various statements, data and physics concepts to design solution designs. Examples of student answers are as follows:

> [L1] :"The best heat-conducting aluminum no. 4 with a thermal conductivity of 222 W/m℃ . The price is also relatively cheap. Then the wood as the handle for the pot because it does not conduct heat so it is safe for the handle"
>
> [P3] : "Aluminum can conduct heat and silicone is used to block the heat so it doesn't get hot when lifting the pan"

The results showed that there were one male student and one female student in the category high. In the low category answers, there is also one male student and one female student. This shows that the students' analytical skills at this stage are the same.

Thestages are imagine and plan interrelated which shows that students' ability

to plan solutions based on the relationship between statements and physics concepts is the same. This can happen because of the understanding of the material that each student has. This is in accordance with the statement of Mulyadi, et al in Riska (2018) that concept knowledge is the basis for finding solutions and an error can occur due to ignorance of the concept.

2. Groups

At the end of the learning activity the students were divided into several groups, each consisting of one female student and one male student. Each group will discuss to find a solution to a physical phenomenon. The results of the discussion will be analyzed based on indicators of critical thinking skills for each student. In this group assignment, students will apply all stages of EDP from ask, imagine, plan, create to improve.

a. Ask

The critical thinking indicator used at this stage is an interpretation indicator. At this stage it consists of several questions that invite students to discuss a description of the problem that occurs, why the problem occurs, what is needed to solve the problem and what physics concepts underlie the problem. During the discussion, it was shown that male and female students were equally able to interpret the problem. However, there are differences in the characteristics of the problem interpretation process between male students and female students.

Female students were more detailed in interpreting the problem and strongly referred to the description of the problem at hand. Meanwhile, male students tend to be more imaginative in interpreting problems according to their understanding and do not really refer to the description of the problems presented. Mhlanga (2017) revealed that women are more accurate and detailed than men. In addition, Elliot, et al in Sari (2016) also stated that female students were more accurate and detailed, while male students were more critical in various interpretations. Example of student discussion:

> [L1] : “Yes, it can be used for solar panels. You can actually use it, actually a turbine that is spinning in water” (gives another idea)
>
> [P1] : “Ow, yes, you can. But in the description, you are asked to make a cooling device without electricity” (refuting)
>
> [L1] : “Ow without electricity, yes, it was also unclear when I read it. This means that what is needed is a traditional cooling device.”

b. Imagine

Imagine is an activity carried out by students by making pictures of solutions that suit their needs based on previous knowledge. The critical thinking indicator used at this stage is analysis, namely the ability to connect various information, data, knowledge to give judgments and opinions. At this stage, each student in the group begins to provide opinions and ideas to get a solution that fits the existing problem.

The results of the discussion showed that the ideas that emerged were mostly given by male students compared to female students. Male students are able to provide ideas by expressing the reasons underlying the idea, although sometimes the ideas and reasons given are not in accordance with the existing conditions. Meanwhile, female students only mentioned ideas without giving explanations or reasons underlying their ideas and female students tended to only give directions to suit the conditions of the problem. Example of student discussion:

> [P1] : "In my opinion, I will make the cooler using earthenware pots." (Conveying the idea)
>
> [L1] : "Use earthenware or burlap sack. In my opinion, I can use a burlap sack which will absorb the water up to the top. The nature of the burlap sack can absorb water. Do you know the burlap sack?” (Submitting ideas according to concepts)

Dominance of male students in giving opinions can occur because based on aspects of problem solving using logical rules, male students are more likely to think flexibly compared to female students who are more rigid and limited (Firmanti, 2017) . In addition, Cruickshank (2014) states that the main difference between boys and girls is that girls more often improve their language skills (spelling, writing and reading) and verbal abilities, while boys more often improve their

abilities in mathematical reasoning and reading skills. spatial relations or see the relationship between objects.

c. Plan

In thestage, plan students begin to discuss and explain in more detail the solutions chosen in the previous stage to be designed in a design based on the function of tools and materials in accordance with related physics concepts. The critical thinking indicator used at this stage is the analytical ability to connect various statements, data and physics concepts to design a solution design. At this stage, male students more often gave opinions and ideas related to the design of solutions along with explanations of the scientific concepts that underlie these ideas, although some parts of the ideas and explanations were less appropriate and doubtful. Meanwhile, female students are more likely to follow the opinions of male students in their group. Example of student discussion:

[P2]: "So what do you need?"

[L2] : "It's wood for storage or the cooler is the same as solar panels as electricity" (delivering an idea that doesn't fit the conditions)

[P2] : "Then how do you use wood to cool it down. If it is only connected to the panel"

[L2] : "Do you just use a burlap sack to moisten it and then cover it all over the frame"

[P2] : "What can I do?"

[L2]: "Yes, when it's wet, the temperature will drop."

This can happen because male students tend to think flexibly compared to female students (Firmanti, 2017). Another distinguishing character is that men more often improve their ability in mathematical reasoning and spatial relations or see relationships between objects, while women more often improve their skills in language arts and verbal skills (Cruickshank 2014).

d. Create

At this stage students make a design solution design by showing scientific data to explain that the solution can be used. The critical thinking indicator used is analysis. Students will integrate all information, physics concepts and plans from the results of previous discussions to be poured into a design form. Criteria and limitations are important to make students think of solutions that suit the conditions of the problem. Example of student discussion:

[P2]: "Okay, okay (while writing). Then this is why the solution that we have chosen can work well"

[L2] : "Just like this. Because it does not require direct electrical energy, that is, it uses solar power from solar radiation which can generate electricity" (while writing)

The group discussion showed that students had not fully been able to provide an explanation by combining all the information and physics concepts that had been obtained previously to ensure the chosen solution. will work. This can happen because students do not yet have a good understanding to integrate all the information to be poured in the form of a solution design. This is in accordance with the statement of Mulyadi, et al in Riska (2018) that an error can occur due to ignorance of the concept. This also shows that his critical thinking ability is still limited where in the process of digging up information that meets intellectual standards of reasoning, developing awareness of concepts and ideas that meet the standards is clear, but when applying the concept is not appropriate, the point of view of problem solving is not clear, the reasoning is also unclear and illogical (Kurniasih, 2010).

e. Improve

At the last stage of this EDP students will assess the effectiveness of the design in solving problems and revise the previous design if it is considered less effective. Critical thinking indicators used at this stage are evaluation and inference. The results of the discussion show that male students are more able to give an assessment of the effectiveness of the solution design. Example of student discussion:

[L1]: "If our strengths are economical, the materials are easy to obtain"

[P1]: "The concept is also simple"

[P1]: "What are the drawbacks?"

[L1]: "The pottery shape should be conical so that it cools quickly, as a result, what we have is slow in decreasing the temperature" (giving an opinion according to the concept)

This can happen because male students dominate in the process of conveying ideas and ideas, so students boys can better understand the ideas or ideas that have been conveyed by providing logical reasons for drawing a conclusion.These results are in line with research conducted by Sukayasa (2014) that in solving problems, male students tend to be able to represent things that based on the conclusions made with logical arguments compared to female students.

Interview data are used to confirm students' critical thinking skills during the discussion process. From the interview data it shows that students' critical thinking skills are in accordance with the results of the analysis of the discussion process. The results of the interviews are presented in table 2. as follows:

Table 2. Description Interview Results

No.	Students	Description of Interview Results
1	L1	In providing an overview of the problems that occurred is still not entirely correct. Students still cannot describe according to the statements, data, and information presented. Then, in explaining the physics concepts used in completing the solution, it is appropriate. However, some sections show that students are still unable to relate and explain the physics concepts mentioned with the solutions offered.
2	L2	Students are able and precise in describing problems that occur based on the information and data presented. according to the description provided. Students are still unable to connect the selected physics concepts with the solutions made, even though the physics concepts mentioned are correct.
3	P1	Students are able to describe problems and phenomena that occur based on information and data presented appropriately. Students have not been able to determine the concept of physics in accordance with the phenomena that occur. In giving opinions regarding the solutions offered, they also have not been able to connect between the concepts of physics and the solution chosen.
4	P2	Students are able to explain and describe problems or phenomena that occur appropriately according to the description. However, students do not understand the concepts of physics that exist in the phenomenon, so that in providing the solution of the problem that occurs is not biased.

4. CONCLUSION

Based on the critical thinking indicators, there are differences in characteristics between male and female students in the problem solving process. However, overall there is no significant difference between the critical thinking abilities of male and female students. Female students are more detailed and accurate in understanding and interpreting problems and tend to be limited in generating ideas than male students. Meanwhile, male students are more imaginative in linking various statements to express ideas, even though some solutions or ideas that appear are not right. However, both male and female students did not fully understand the concepts of physics related to the solutions to existing problems. So that the statements and opinions given regarding solutions tend to be less clear and less logical. Because the understanding of physics concepts and previous knowledge of science really builds students' critical thinking skills when working on the tasks in the module.

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