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Profile of Critical Thinking Skills of Students on Hydraulic Pump Theme Learning in One of the Junior High Schools in Sumedang Regency

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Abstract

This study addresses students' critical thinking skills profiles in learning about hydraulic pumps under a STEM Quartet Instructional Framework using a problem-based learning approach. This study was implemented in a VIII class at one Indonesian junior high school. Data collection and analysis considered learning observations, teacher interviews, document studies, and recordings (audio and video). The learning design is problem-based, consisting of two school-based activities and homework projects. The learning of hydraulic pump design uses a contextual problem related to the student's daily life in Sumedang Regency, where the students live. The discussion allowed students to demonstrate critical thinking indicators. The profile of students' critical thinking skills is seen from the appearance of indicators of critical thinking skills. The highest indicators of student critical thinking skills occurred in the first face-to-face meeting: asked questions (203 times), identified concepts (124 times), and delivered assumptions (188 times). The highest Indicators of critical thinking skills at the second face-to-face meeting are: described data or information (227 times), delivered assumptions (148 times), and asked questions (125 times). The indicators reflect differences in the stages of the first and second sessions. Meanwhile, the least indicator of critical thinking skills at the first and second face-to-face meetings was ‘conveying the goal’. The lack of appearance of that indicator was influenced by the low attention of students to the goal. The results were influenced by the learning phases and individual and group characteristics.

Keywords: Lesson design · STEM learning · Hydraulic pump · Transcript Based Lesson Analysis (TBLA) · Students’ critical thinking skills

INTRODUCTION

The 2013 Indonesian curriculum emphasizes student-centered learning activities and focuses on 21st-century skills. Twenty-First Century skills are collaboration, communication, critical thinking, problem-solving, and creativity. Learning in schools is not only about students gaining knowledge but also about developing critical thinking, communication, creativity, and collaboration.

One key aspect of the 21st Century skills is the ability to think critically. Critical thinking skills are needed to form new ideas and implement innovations in addressing the challenges of global competition. Critical thinking skills also allow people to respond to the challenges of the 21st century. The development of critical thinking skills in school education is a priority (Martincová & Lukešová, 2015).

However, contemporary learning environments are often not set up to facilitate 21st-century skills. Most of the learning in schools is dominated by teacher explanations or teacher-generated questions that encourage short answers with limited opportunity for students to think deeply, critically, and creatively (Davies *et al.*, 2017; Lehesvouri *et al*, 2011; Viiri & Saari, 2006).

According to Paul and Elder (2005), critical thinking skills are the ability to master the process of analyzing and assessing the results of thinking to improve student critical thinking. Critical thinking relies on knowledge of the most basic structures in the elements of thinking and the most basic

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intellectual standards for thinking (universal intellectual standards). A person can be said to be able to have the ability to think critically if they meet the basic elements of thinking against universal intellectual standards. These standards are conveyed clearly (*clarity*), accurate (*accuracy*), relevant (*relevance)*, according to logic (*logically*), breadth (broadly), precision (*precisely*), Honest or Fair (*fairly*), deep (*Deeply*), complete *(comprehensively*), and significant (*significantly*). Applying the basic elements of thinking, following the thinking ability standards set by Paul and Elder (2005), requires appropriate pedagogy to facilitate optimal student critical thinking skills. Research and evaluation ensure the effective connection of pedagogy and the desired critical skills development.

A general learning approach teachers can use to improve student's critical thinking is the STEM Quartet Instructional Framework (*Science, Technology, Engineering, and Mathematics).* This approach raises specific contextual problems first and then integrates and connects these problems across the four STEM fields. When learning under a STEM quartet approach, students receive practical problems to solve, applying engineering and other solutions. Students are trained to think critically, systematically plan, and apply critical thinking to solve these realistic problems (Tan et al., 2019).

Problem Based Learning (PBL) is one learning approach that teachers can use under a STEM Quartet Instructional Framework. In PBL, students are trained in their reasoning abilities to face various daily problems in group and individual situations. Daily problems described in learning situations will be more appropriate if they are associated with various aspects of life and are not limited to the immediate scope of learning (Rahmawati et al., 2016). One of the science learning materials related to everyday problems aligned with a STEM learning approach is the physic topic "pressure in liquids." Students in everyday life often encounter this concept. However, they mostly find it abstract and challenging to understand. The phenomenon of the water pressure makes this science topic very appropriate for a STEM *Problem-Based Learning* (PBL) approach if it is associated with scientific and engineering processes elements.

Previous research on STEM learning examining critical thinking skills mostly uses quantitative research methodology (Adiwiguna et al., 2019; Ariyatun & Octavianelis, 2020; Farwati et al., 2017; Putri et al., 2020). Most research looks at student assessment results, not the complexities of the learning process and learner experiences. Research that draws upon qualitative methodology is needed to have a deeper understanding of teaching and learning critical thinking skills. The qualitative research methodology allows analyses of the complexity of student critical thinking skill development processes. Therefore, this current research addresses this gap of understanding. The research reported here describes Indonesian junior high school students' critical thinking skills development in their learning about hydraulic rams. Hydraulic rams are water pumps that do not use an artificial power source but use gravity and inertia to pump water.

METHODS

The broad methodology of the research design of this study is qualitative. A research design is developed based on a more in-depth problem picture. The design emerges from investigating the quality of relationships, activities, situations, or materials (Fraenkel et al., 2012). The data generated from this study are in the form of conversations and observed behaviors of the students during the learning process, then the resulting data is analyzed and described.

This research occurred in a public junior high school in Sumedang Regency, Indonesia. Sixteen students of class VIII were selected using a purposive *sampling technique*. Purposive sampling involved consideration of the characteristics of high school classes and students known by Nurmalasari, the teacher (Ali, 2013).

This research procedure involved three stages, namely the preparation stage, the data collection stage, and the data analysis stage. The preparation stage involved a literature review and research plan. During the data collection stage, data were obtained in three stages of didactic analysis through *lesson study learning* by focusing on the *lesson design stage* (didactic analysis before learning), *observation* (didactic analysis during learning), and reflection (didactic analysis after learning).

The instruments used in this study were: lesson design, student worksheets (LKPD), observation sheets, and audio and video recordings. Based on Paul and Elder's (2006) critical thinking indicators, students' critical thinking skills activities were analyzed using Transcript Based Lesson Analysis (TBLA) using audio and video transcripts and drawing upon other learning artifacts.

RESULTS AND DISCUSSION

The critical thinking profile of students was obtained from the analysis of the results of the learning transcript using the TBLA method. The analysis was conducted to reveal the profile of students' critical thinking skills as a whole and individually in learning.

Critical thinking skills were analyzed based on the analysis of students' speech in learning transcripts using indicators of 'reasoning elements' and 'universal intellectual standards' developed by Paul and Elder (2006). Elements of reasoning, according to Paul and Elder (2006) comprise eight aspects, namely: conveying goals, asking questions, collecting and presenting data/information, identifying and explaining concepts, thinking from various points of view and being open, conveying assumptions to form a point of view, making conclusions, communicating the implications of the problem. The eight elements of reasoning are measured against universal intellectual standards. The universal intellectual standard used in this study is whether the elements of reasoning produced are precise, complex, significant, honest, relevant, accurate, and profound. The measurement of the reasoning elements against the universal intellectual standard is adjusted to the learning phase.

STEM learning on the theme of water pumps without electricity comprises two face-to-face learning meetings and projects at home. The first meeting was in the STEM learning stage, determining questions based on the problems presented. In this case, the problem of water supply difficulties in the student environment - Sumedang Regency. Then the class discussed designing a water pump without electricity, using gravity, water pressure, the inertia of water flow, and capturing kinetic energy. The process of making the water pump without electricity continued at home. In manufacturing, students need the help of parents and technicians to make a water pump without electricity. The second meeting conducted trials of the student-designed water pumps. Each group presented the results of the water pump trials, followed by a redesign, and closed with a review by the teacher at the end of the lesson. Analysis of the critical thinking skills was done at each stage to produce a complete picture of the profile of critical thinking skills of the students in these activities.

STEM learning about a hydraulic ram utilizes the concept of liquid pressure as a solution to a practical problem, namely pumping water without using electricity to address a water supply problem. The learning activity comprised two meetings. The first was a discussion about the design of the water pump, and the second was to carry out a trial and evaluation of the pump. Analysis of critical thinking skills occurred in both meetings. Overall, the profile of students' critical thinking skills at the first meeting appears in the graph in Figure 1.

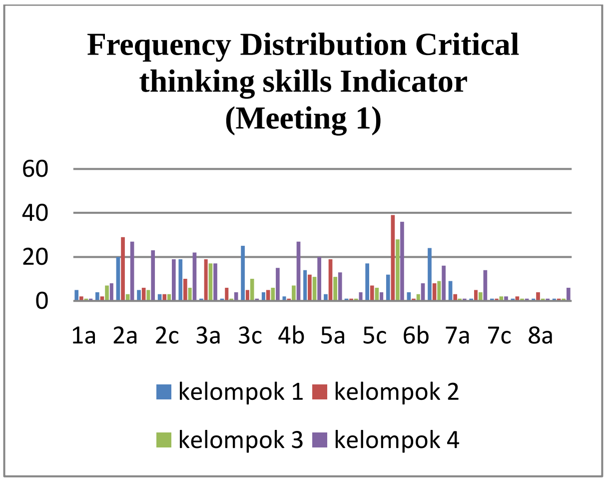

Figure 1. Frequency distribution of critical thinking skills per indicator (meeting 1)

Based on the analysis of critical thinking skills data of the first meeting, the indicator that appears more often is the second indicator of 'asking questions' (203 times), indicator four, 'identifying and explaining the concept' (124 times), and indicator six 'conveying assumptions to form a point of view' (188 times). The frequency of occurrence is influenced by the learning phase that occurs.

The indicator that appears the most is the indicator asking questions. In asking this question, students ask questions in learning 203 times. The indicators for asking questions are divided according to Paul and Elder (2006)'s universal intellectual standards into several sub-indicators, namely asking questions clearly (2a), asking relevant questions (2b), and asking in-depth questions (2c), and asking questions from different points of view. (2d). Of the four sub-indicators, the one that appears the most is the sub-indicator asking questions clearly (2a) as much as 79 times, and the second most is the sub-indicator asking questions from a different point of view (2d) which is 37 times. The questions asked by the students were primarily addressed to other students in the group discussion phase to determine the design of the water pump to be made.

This is obtained from the analysis of the emergence of each indicator based on the learning time series (index). The appearance of the indicator asking questions clearly (2a) can be seen in the graph of the appearance of the indicator based on the time series (index) below:

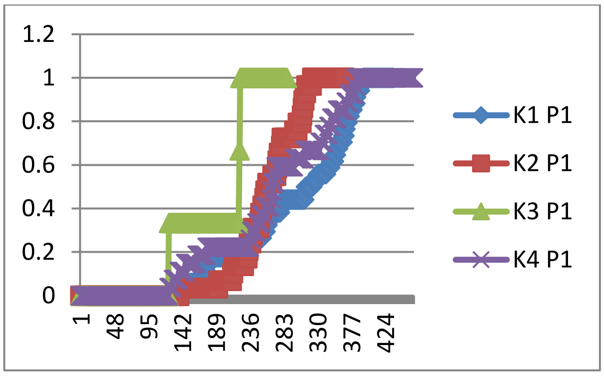

Figure 2. Occurrence of indicator 2a based on time series (index)

Based on the graph of the emergence of the critical thinking indicator 2a, which asks questions starting from the time index 116 to the time index 461. At the time index 113, learning is in the initial discussion phase in groups to answer learning problems presented by the teacher in the form of water difficulties experienced by residents in mountain settlements. The questions asked clearly occurred in Group Two and Group Four discussions. This means that when students are presented with problems in learning critical thinking skills in the form of questions, more questions appear.

The problem the teacher presented in this lesson is water access difficulties in mountainous settlements experienced in the area around the student's residence. In the Sumedang area, there are many high-flow rivers, but the local people have to go down to the river to get water. Students are asked to solve the problem using the concept of liquid pressure, the learning material at that time. These problems are seen or experienced directly by students. These contextual problems result in a higher frequency number of indicators for students' critical thinking skills in this phase. This pattern shows that contextual problems can improve students' critical thinking skills. Some of the questions that were clearly conveyed by students in Group Two discussions and to answer learning problems can be seen from the dialogue snippet below. Snippets of dialogue in Group One discussion when answering problems in LKPD.

Another indicator that appears most frequently at the first meeting is the indicator to identify or explain the concept. The results of the frequency of occurrence analysis based on the learning time series (index) show that the two indicators often appeared in group dialogues to discuss the design of a water pump without electricity. In indicator four in the form of identifying or explaining concepts based on universal intellectual standards (Paul and Elder, 2006) is divided into several sub-indicators, namely (4a) identifying or explaining certain concepts clearly, (4b) identifying concepts with the right theory, and (4c) identifying concepts relevant to the problem. The results of the analysis show that the highest frequency of sub-indicators is identifying concepts relevant to the problem (57 times), followed by sub-indicators explaining certain concepts clearly (4a) (37 times) and identifying concepts with the right theory (4b) (30 times).

The analysis of the sub-indicators based on the learning time series (index) showed that the sub-indicators that appeared the most were related to the learning phase that occurred. The sub-indicators identify concepts that are relevant to the problem (4c) that often occur during group discussions to determine the design of a water pump without electricity to be made. Students discuss the tools and materials that could be used as well as drawings of the design of the water pump. The results of the analysis of sub-indicators to identify concepts relevant to the problem (4c) can be seen in Figure 3 below.

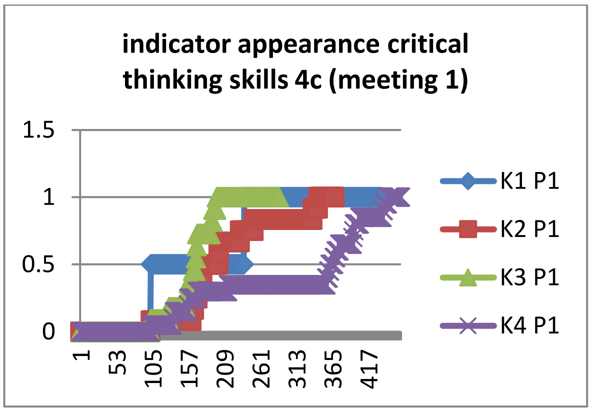

Figure 3. Occurrences of 4c indicator based on n time series (index)

Based on the analysis of the sub-indicators of the learning time series (index) it was found that the sub-indicator (4c) first appeared on the 93rd index, peaked at the 161-286 index, and continued to decline until the 461st index. At index 93, students in the group discussion phase determine tools and materials to be used to design and build the water pump. Identification of relevant concepts based on the problems presented by the teacher culminated when students described how to design a water pump without electricity to be made. Most students relate the concept of liquid pressure to the water pump. This shows that critical thinking skills in the element of thinking in identifying and explaining concepts will appear when students are allowed to explain their problem solving provided by the teacher based on the concept of the learning material being studied. This pattern means that the more opportunities given to students to discuss linking learning materials with the problems given, the more critical thinking skills in terms of identifying concepts relevant to the problem will be demonstrated. Students' expressions when identifying concepts relevant to problems in learning are described in the dialogue snippet below.

The third most appearing indicator in the first meeting learning is the sixth indicator regarding conveying assumptions to form a point of view that appeared 188 times. The indicator conveying the assumptions to form this point of view is divided into several sub-indicators based on the universal intellectual standards of Paul Elder (2006). The sub-indicators in the indicator convey assumptions to form this point of view, namely conveying personal assumptions regarding agreement/disagreement clearly with other opinions (6a), conveying assumptions following the problem (6b), and conveying assumptions that are more complex or supported by certain theories or concepts (6c). At the first meeting, the highest occurrence of sub-indicator 6a was 115 times, then 6c was 57 times and 6b was 16 times in learning.

The emergence of the three sub-indicators is related to the learning phase. The analysis results of sub-indicator 6a in the form of personal assumptions regarding apparent agreement/disagreement on other opinions can be seen based on Figure 4 below.

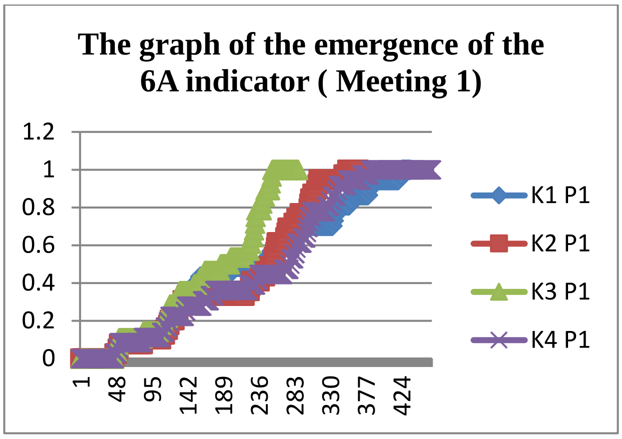

Figure 4. Occurrences of indicator 6a based on time series (index)

In sub-indicator 6a, conveying personal assumptions about agreement/disagreement clearly, other opinions appear in the initial phase until the end of learning. In this sub-indicator, it first appeared on the learning index 47 then rose significantly and lasted until index 461. At index 47 learning in the teacher phase presented learning problems in front of the class. The teacher and students identify the problems that occur in the pictures presented by the teacher in front of the class. In this phase, students convey assumptions or opinions regarding agreement/disagreement with the teacher's opinion or the opinions of other students. This sub-indicator maximally appears during the learning phase of the discussion regarding the design of the water pump to be made. Sub-indicators convey this assumption that occurs in almost all learning. In the appearance of sub-indicator 6a, it is different from several other reasoning element indicators that will appear during certain phases of learning. These results mean that the ability to think critically in the sub-indicators of conveying assumptions does not completely depend on the learning phase but depends on the opportunities provided by the teacher or other students in the discussion to express opinions clearly. This can be illustrated by the snippet in the dialog shown below.

Profile analysis of critical thinking skills was also carried out in learning at the second meeting. At the second meeting, students presented and conducted trials on the results of the water pump without electricity that had been made. The profile of critical thinking skills at the second meeting was dominated by the 3rd indicator collecting and presenting data or information, followed by the 2nd indicator asking questions, and the sixth conveying assumptions to form a point of view. The results of the frequency distribution of critical thinking skills indicators can be seen in Figure 5 below.

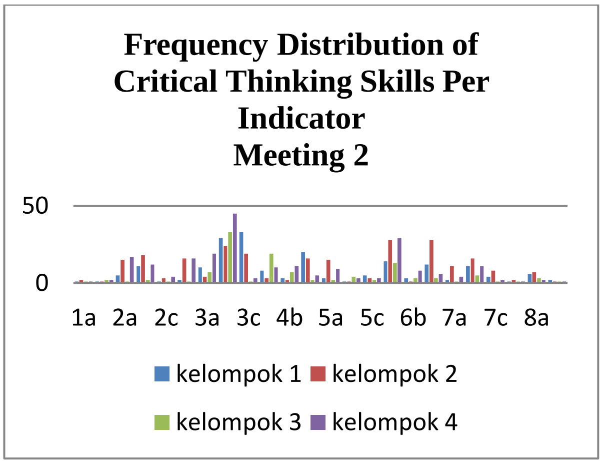

Figure 5. Frequency distribution of Critical Thinking skills (meeting 2)

Based on the analysis of students' critical thinking skills, indicators at the second meeting obtained the results of the highest frequency of critical thinking skills indicators, namely the 3rd indicator collecting and presenting data or information 227 times, then followed by the 6th indicator conveying assumptions to form a point of view 148 times and the indicator 2nd asked the question 125 times.

In the third indicator, collecting and presenting data or information is divided again according to the universal intellectual standards of Paul and Elder (2006) into 3 sub-indicators, namely presenting information clearly (3a), presenting accurate data according to the results of experiments that have been carried out (3b) and presenting data logically according to the learning problem (3b). In the three sub-indicators, the highest to lowest frequency in a row is presenting accurate data according to the results of experiments that have been carried out (3b) as many as 131 times, presenting data logically according to learning problems (3c) 56 times and presenting information clearly (3a) 40 times. The magnitude of the frequency of sub- indicator 3b is influenced by the learning phase that occurs. The emergence of these sub-indicators can be seen based on the results of the analysis of the emergence of each sub-indicator against the learning time series (index).

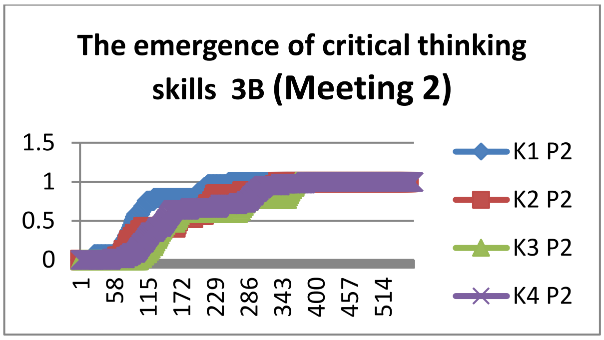

Figure 6. Emergence of sub-indicator 3b meeting 2

Based on the results of the analysis of the emergence of the sub-indicators seen by the time series (index) of learning, it can be seen that sub-indicator 3b presents accurate data according to the experimental results that appear first at index 55. This index learning is in the trial phase of a water pump without electricity. The emergence of the critical thinking skills indicator, sub-indicator 6a, lasts until the end of the lesson when students present the data from the test results of the tool and present it in front of the class. This means that the ability to present data accurately depends on how students carry out the learning phase. In this study, a trial of the water pump is carried out. The trial requires students to be better able to present accurate experimental data following the results of the trials. An overview of the ability to present data based on test results (sub-indicator 3b) is seen in the dialogue snippet below.

At the second meeting, the second most frequently occurring indicator frequency was the 6th indicator conveying assumptions to form a point of view 148 times. At the second meeting, the sub-indicators of the indicators conveyed the most common assumptions, namely sub-indicator 6a, which conveyed clear assumptions about agreement/disagreement 84 times. The results of the analysis of the emergence of sub-indicator 6a can be seen in Figure 7 below.

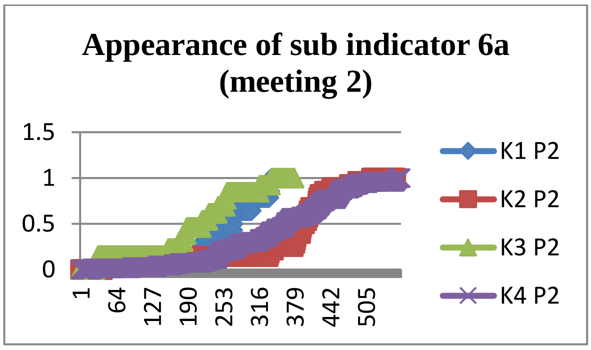

Figure 7. Emergence of sub-indicator 6a meeting 2

Based on the analysis of the emergence of sub-indicator 6a above, it can be seen that sub-indicator 6a first appears in the 28th learning index and then increases to a maximum of 325 learning index. In the 28th learning index, the learning phase occurs when the teacher checks the design of the water pump without electricity that has been made. The ability to convey assumptions about of maximum agreement/disagreement occurs at a learning index between 325-541. In this index, the learning is in the trial phase of the water pump. The discussion phase to conduct trials spurred students to convey more assumptions in group discussions. This is slightly different from the appearance of sub-indicator 6a at the first meeting. At the first meeting, the emergence of sub-indicator 6a did not depend on the learning phase. However, it depended on the opportunities provided by the teacher or other students in the discussion to express opinions clearly. At the second meeting, it was found that the emergence of sub-indicator 6a tends to increase more when there is a discussion to conduct experiments or trials. This pattern shows that the existence of an experimental or trial phase carried out by students will further encourage students to think more critically in conveying data from the results of the trials carried out. The description of the appearance of sub-indicator 6a can be seen from the dialogue snippet below.

S2	:	So the cause was the load was too heavy and the air tube was leaking
S1	:	*That's right, I installed the wrong tool so it wouldn't leak, which this morning I opened, I installed the wrong tool*
S1	:	Cause the pump doesn't work
S3, S4	:	*Yes Wrongly installed the tool*

The third indicator that appears the most at the second meeting is indicator 2 asking 125 questions. This means that the indicator of asking this question appears a lot both at the first meeting and the second meeting in learning. At the second meeting, the sub-indicators asked the most questions, namely sub-indicator 2b, which asks questions relevant to the problem. To find out how far the emergence of the indicator asking questions in sub-indicator 2b, an analysis of the appearance of the sub-indicator was carried out based on the learning time series (index).

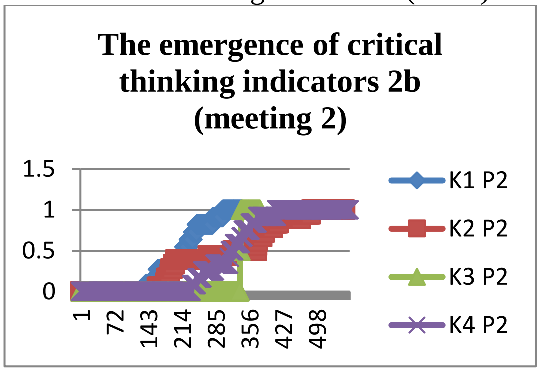

Figure 8. Emergence of Sub-indicator 2b meeting 2

Based on the analysis of the emergence of sub-indicator 2b asking questions that are relevant to the problem, it can be seen that the appearance of the sub-indicator for the first time at index 136 rose gradually to index 541. At index 136 the learning was in the trial phase of the water pump without electricity to be made. In this phase, many questions arise from students in group discussions. Students must determine how much pressure in the water pump is made. This triggers students to think more critically by asking relevant questions. This finding is in line with the emergence of the indicator asking questions at the first meeting when students are given more opportunities to solve contextual problems. It shows the ability of students to think critically with the element of reasoning in asking questions will tend to be higher. An overview of student questions in the tool testing phase can be seen in the dialogue snippet below.

S1	:	*Less burden?*
S2	:	Less burden
S4	:	It's less burdensome because if the load is added, it's quieter
S1	:	yes

S1 : *The volume is five liters, the time?*
S2 : The time is 27.68
G : 27.68, we round it up to 28, okay, measure the debit
S1 *how to measure discharge?*
S2 : Value divided by time
G : good
S2 : The discharge is 5.6 seconds

Based on the results of the analysis of critical thinking skills in each of the indicators for learning meetings 1 and 2 above, it can be seen that there are indicators that appear at least in learning both at the first meeting and the second meeting, namely indicator One 'determines goals'. The indicators for conveying goals are divided into two sub-indicators based on universal intellectual standards, namely clearly conveying learning objectives (1a) and conveying objectives relevant to the problem (1b). Delivering clear learning objectives meant here is conveying the general purpose of project work, namely solving water problems while conveying relevant objectives means that students convey the objectives of carrying out learning activities based on the problems that the teacher has conveyed. The results of the graphic analysis of the emergence of sub-indicator 1a at the first and second meetings can be seen in Figures 9 below.

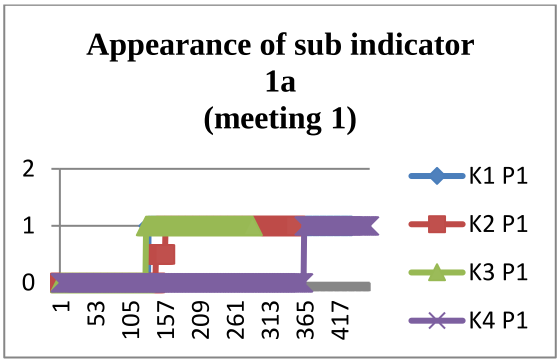

Figure 9. Emergences of sub indicator 1a (meeting 1)

In the graph above, the appearance of sub-indicator 1a at the first meeting appeared once in groups 1, 2, and 4 and appeared 2 times in group 2. In LKPD, one of the students immediately answered the question without any group discussion. Meanwhile, in Group Two, there were two words about the learning objectives that were asked in the LAPD. This is what causes group 2 to appear twice. The same thing happened in the second meeting. The lack of group discussions on the purpose of making the water pump is evidence that students' critical thinking skills in indicators of conveying goals in this meeting depend on requests to explain objectives in learning. This means that students will immediately convey the purpose of working on a water pump project without electricity either directly orally or in writing by the teacher without the need to have discussions with other students in the group.

Based on the analysis of the frequency and occurrence per indicator of critical thinking skills in the overall learning, the results show that the frequency of occurrence is influenced by the stages of STEM learning activities that occur. At the first meeting, students are in the learning stage to determine the basic questions from the problems presented by the teacher. In learning with the STEM quartet approach, the problems presented are problems that exist in everyday life regarding the problem of water supply difficulties around their environment. Students describe problems and find the best solution to the problems that exist in their environment. This learning stage encourages students to ask more questions. So that at the first meeting, the indicator asking questions tends to appear more than the other indicators, which is 203 times. In addition, in the first lesson, students designed a water pump without electricity which was used as a solution to water difficulties in learning problems. Discussions in groups to determine the design of the water pump caused the indicators to identify and explain concepts at this meeting to appear 124 times. This is because students try to discuss, identify and explain the concepts used in the workings of the water pump being designed. At the second meeting, the indicator that appeared the most was the 3rd indicator regarding collecting and presenting data or information as much as 227 times, then followed by the 6th indicator conveying assumptions to form 148 points of view. Testing the water pump, redesigning the pump, and reviewing the activities carried out together. The trial and redesign direct students to think more in collecting test data and form thoughts and assumptions about why the test results can be formed. The results of the frequency at the first and second meetings show that the emergence of indicators of critical thinking skills is closely related to the learning activities carried out by students.

CONCLUSION

Profile of students' critical thinking skills can be seen from the indicators of critical thinking skills that appear. The indicators of critical thinking skills that appear the most in the first meeting learning are asking questions (203 times), identifying concepts (124 times), and conveying assumptions (188 times). The indicators of critical thinking skills that appear the most at the second meeting are presenting data or information (227 times), conveying assumptions (148 times), and asking questions (125 times). Meanwhile, the indicator of critical thinking skills that appeared the least in the first and second meetings was 'conveying the goal'. The lack of student attention influences the lack of appearance of indicators conveying this goal to convey the objectives of learning and the objectives of the activities carried out in learning.

Referring to the process and results obtained in this study, the authors provide recommendations for further research to be carried out by mapping students' characteristics when measuring students' critical thinking skills. This will help record how the changes formed when the research was conducted and also know the influence of individual characteristics in learning on students' critical thinking skills in more depth. Research using a sample of students in research that is more *talk-active* is also very necessary. This research uses TBLA analysis (*transcript-based lesson analysis*) which will be easier to do when students are *talk-active participants*.

REFERENCES

Adiwiguna, P. S., Dantes, N., & Gunamantha, I. M. (2019). *Effect of STEM-oriented Problem Based Learning (PBL) Model on Critical Thinking and Scientific Literacy Skills for Fifth Grade Elementary School Students in Gusti Ketut Puja Group I, 3* (2), 94–103.

Ariyatun, A., & Octavianelis, D. F. (2020). The Influence of Stem Integrated Problem Based Learning Model on Students' Critical Thinking Ability. *JEC: Journal of Educational Chemistry* , *2* (1), 33.

Cáceres, M., Nussbaum, M., & Ortiz, J. (2020). Integrating critical thinking into the classroom: A teacher's perspective. *Thinking Skills and Creativity*, *37*, 100674.

Farwati, R., Permanasari, A., Firman, H., & Suhery, T. (2017). The integration of problem based learning in STEM education is oriented towards the actualization of environmental literacy and creativity. *Proceedings of the National Science Education Seminar* , 198–206.

Fraenkel, J. R., Wallen, N. E., & Hyun, H. H. (2012). *How to Design and Evaluate Research in education*. McGraw-Hill.

Martincová, J., & Lukešová, M. (2015). Critical Thinking as a Tool for Managing Intercultural Conflicts. *Procedia - Social and Behavioral Sciences*, *171*, 1255–1264.

Paul, R., Niewoehner, R., & Elder, L. (2019). The Thinker's Guide to Engineering Reasoning: Based on Critical thinking Concepts and Principles. In *Rowman & Littlefield* .

Rahmawati, I., Hidayat, A., & Rahayu, S. (2016). Mastery of Science Concepts for Junior High School Students on Pressure Materials in Liquids and Its Applications. *JPS (Journal of Science Education)*, *4*(3), 102–112.