Analyzing mathematical connection skill in solving a contextual problem

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Abstract. Mathematical connection skill is needed by students to connect mathematics theory and contextual problem solving. As state, in NCTM that the mathematical connections skill is one of the four competencies needed to face the industrial revolution 4.0. According to NCTM, there are three mathematical connection skills, namely modeling problems, applying obtained concepts and procedures also expanding mathematics ideas. The purpose of this study was to describe the class X student’s mathematical connection skill at Boyolali High School, Central Java in doing a contextual problem in one variable linear inequality. This research was a comparative descriptive study with qualitative methods involving 15 students from 5 schools as participants. The results showed that students' mathematical connection skill is still low. We saw this from the indicators showed that the students were unable in modeling the contextual problems correctly, students were not able in applying the obtained the concepts and procedures also getting difficulty in expanding mathematics ideas.

1. Introduction
Contextual problems are problems that are designed as real experiences for students. The solution of contextual problems requires students' ability to connect between material that they have learned previously. In line with the demands of the industrial revolution, 4.0 students can connect the things they have mastered to solve a problem. The meaning of ability is mathematical connections skill. When students connect mathematical ideas, their understanding is deeper and more lasting, and they come to view mathematics as a coherent whole. By solving mathematical problems, students gain ways of thinking, habits of persistence and curiosity, and confidence in unfamiliar situations that serve them well outside the mathematics classroom [1].

Students recognized algebra since 7th grade of junior high school and continued studying in subsequent classes. Linear inequality is the initial part of the concept of algebra, so that considered the contextual issues regarding the material having been mastered by high school students. Contextual problems are real or concrete problems close to the life of students [2]. Therefore, contextual problems are present a real environment for students and apply to everyday life. While the contextual mathematics problem is a mathematical problem that presents a situation that is or has been experienced by students and uses various mathematical concepts in its solution. Contextual problems given to students must provide information that can be arranged mathematically and provide
opportunities for students to solve problems using the knowledge and experience they have acquired [3]. In this research, we relate contextual problems given to students to the inequality of one variable.

Based on observation in Senior High School students and interviewing mathematics teachers in Boyolali, many students think mathematics is a difficult subject. This is because most of the students experience difficulties in understanding the problem and determining the formula or theory that will solve the problem [4]. In addition, the weak ability of students to change the form of context to the form of a mathematical model appropriately so that students fail in determining the right solution [5]. One activity to build students’ mathematical connections is to get students used to solve contextual problems. This happens because students need to find the connection of concepts or theorems used to determine the completion of a problem. We say this ability to be a mathematical connection. When students can connect mathematical ideas, their understanding of mathematics becomes deeper and more durable [1]. Activities that study the relationship between mathematical topics, connect ideas in mathematics and use mathematics as a solution to find answers is an activity that trains students to improve their mathematical connection abilities. If a topic given separately, learning will lose one moment to improve student achievement in mathematics.

In this study, researchers used mathematical connection indicators from NCTM comprising three aspects, namely Modeling Problems, Applying obtained concepts and procedures, and Expanding mathematical ideas. Researchers developed the indicators for every aspect of mathematical connection skill by themselves.

| Tabel 1. Mathematical Connection Indicators |
|--------------------------------------------|
| Aspects                              | Indicators                                                |
| Modeling Problem             | Reading and understanding the problem                     |
|                                 | Capable to predict the completion plan                    |
|                                 | Capable to determine the plan used to resolve the problem |
|                                 | Capable to know the use of notation                       |
| Applying obtained concepts and procedure | Capable to involve prior knowledge in solving problems  |
|                                 | Capable to solve the problem in different concepts        |
|                                 | Capable to do the right procedure                         |
|                                 | Capable to set the result                                 |
| Expanding mathematical ideas      | Capable to connect between mathematical concepts         |
|                                 | Capable to connect mathematics with other disciplines and daily activities |

The aim of this research is describing how the student’s mathematical connection skill are related in the modeling problem, applying obtained concepts and procedures and also expanding mathematical ideas to solve linear inequality with contextual problems.

2. Materials and Methods

2.1. Place and Time of Research
The research took place on September 16-26, 2019 with 45 minutes duration. We conducted the research in 5 different schools in Boyolali. They were SMA Muhammadiyah 4 Andong, SMA Gagatan Karanggeda, SMA Muhammadiyah PK Sambi, SMA N Juwangi dan SMA Muhammadiyah 4 Simo.

2.2. Type of Research
We got data from research result, understand, solve and expect problems. We define the research method as a scientific way to get data with specific purposes and uses [6]. This research used to analyze the mathematical connection skill in solving contextual problems was descriptive and comparative research. We conduct descriptive research to find out the existence of an independent
variable, either one variable or more (a stand-alone variable) without making comparisons or searching for the relationship of variables with each other. While comparative research is a study comparing the state of one or more variables in two or more different samples, or two different times [6]. The application of comparative research in this study was used to determine the comparison of the mathematical connection skill of high school students in Boyolali.

2.3. Samples and populations
The research subjects were all grade X high school students in Boyolali comprising 30 public and private schools. Samples took 15 students. They comprised 3 students in each school. The sampling technique was multi-stage random sampling with three stages. First choose 5 schools out of 30 schools as a cluster, then choose a sub-cluster that was consisting one class from each school and ended with selecting 3 students from the members of sub-cluster. All activities did randomly.

2.4. Data collection techniques
Data collection techniques in this study are test and interview.

2.4.1. Test. We carried the test out as prerequisite material before entering the subject of inequality to find out how understand students in mathematical concepts. In this research, the test questions are in description form. This question is good to apply to all levels of education from elementary to tertiary levels. The abilities expressed through the description test are not only logical thinking skills, but also language skills. The test dimensions of the description are broader and can cover all aspects of cognitive equally. We present the description test in the form of contextual questions where participants often experience that. Participants were answering two contextual questions on the material linear inequality of one variable. The process was lasting for 30 minutes, then continuing with the interview.

2.4.2. Interview. Interview is conversations that is conducted by two or more parties, namely the interviewer (a person who asks questions) and interviewed (a person who gives answers to the questions). Interview is a conversation with a specific purpose [7]. In this study, researchers and participants directly conducted questions and answers to get information verbally to get data that could explain the research problem.

3. Results
The research aimed to describe the mathematical connection skill of Boyolali senior high school students on the linear inequality one variable. Researchers used an NCTM mathematical connection indicator. They developed that to interpret this skill. We measured mathematical connection skill from the results of tests and interviews on 15 students. There were two contextual problems as the test.

**Problem 1**
A car can carry only 1500 kg. The driver and the driver's weight are 140 kg. He will transport boxes of goods, each box weighs 40 kg.

a. How many boxes can be transported in one transport?
b. If he will transport 408 boxes, at least how many times it will transport?

**Problem 2**
The distance between Joko's house and the school is 45 km. The school enters at 07.00. Joko left home at 05.30 on a motorcycle. On the way, his bicycle broke down, then repaired it for 15 minutes. What is the minimum average speed so that Joko is not late for school?
After conducting research on 15 students, researchers got data and analyzed it using three NCTM indicators, namely modeling problems, applying obtained concepts and procedures and expanding mathematical ideas.

3.1. Modeling Problem Aspect

![Diagram of modeling problem aspect](image)

Figure 1. Diagram of modeling problem aspect

Figure 1 shows that in the aspect of modeling problems 40% of participants could read and understand the problem, able to predict the solution plan, able to determine the plan used to solve the problem and know the notation to be used. From these 40%, 13% of participants are very good at modeling problems and another 27% are good. While 60% of participants still experience difficulties in finding the modeling problem indicators of the questions presented. Figure 2 presents one of the participant answers.

![Participant’s worksheet](image)

Figure 2. One of the participant’s worksheet from modeling problem aspect ((a) problem 1, (b) problem 2)

Figure 2 shows that participants were being able to understand the problem, but still not capable to determine the plan used to resolve the problem. Participants were also rewriting the problem and not converting it into mathematical notation. Conversation below resulted from interviews with participants regarding aspects of modeling problem.
Researcher : Figure 2 in Problem 1 point a) why do you write the problem?
Participant : More easy to understand.
Researcher : Have you ever want to change it into notation?
Participant : No madam, I confused to solve it later.
Researcher : From Figure 2 in Problem 1, what they ask?
Participant : Point a) many boxes are transported in one way and point b) number of times transported.
Researcher : In point b) is it only asked how many times is transportation?
Participant : (read the problem again) No madam, there are words “fewest”.
Researcher : Does the existence of the word make a difference?
Participant : No, madam.
Researcher : Figure 2 in Problem 2, where did you get the 90 minute number?
Participant : The arrival time minus the departure time then changed it into minutes.
Researcher : In Problem 2, there is "minimum average speed". Did this make different answer? (Pointing to Figure 2)
Participant : No, madam.

Based on Figure 2 and interview, participants were not expressing contextual problems into mathematical sentences even though they understood the problem. There wasn’t appropriating notation that showed the plan in solving the problem. It showed that the Participants were not understanding symbol that refer to notation of inequality. In Figure 1 showed that 10 participants were having difficulties in determine the plan used to resolving the problem. Builded upon these finding, participants ability in a modeling problem needed to be developed.

3.2. Applying Obtained Concept and Procedure

Figure 3. Diagram of applying obtained concept and procedure aspect

Figure 3 shows that in the applying obtained concepts and procedure aspects, 53% of participant had poorly applying the concepts and procedures that they had learned. The most difficulty experienced by participants when they were performing procedural concept in solving a problem, it would affect the determination of the final results. There were 9 students that cannot work well, and 15 students cannot answer correctly. Figure 4 is one participant answer from the applying obtained concepts and procedure aspects.
Figure 4 showed that students were involving prior knowledge in solving the problem and using many concepts finding the answers but were not having the right result. Next passage is the excerpt of interview regarding aspects of modeling problem.

| Researcher | From problem 1, what did you meant by writing "every 200 there are 5 boxes"? Still remembered how did you thought it? |
|------------|-------------------------------------------------------------------------------------------------------------|
| Participant| I thought because each box had 40 kg weight, then for 200 kg there would be 5 boxes.                       |
| Researcher | You meant 5 came from 200 divided by 40? Then what?                                                         |
| Participant| Yes madam, the maximum accommodate of the car was 1500 kg, then 200 x 7 = 1400. It meant that needed 7 x 5 = 35 boxes. Because the maximum accommodate is 1500 so there was still 100 kg left, every 100 kg needed 2 boxes. So the total is 35 + 2 = 37 squares. |
| Researcher | You said for 100 kg took 2 boxes. You know that 1 box holding 40 kg. There were still 20 kg left. How about that? |
| Participant| I just ignored it.                                                                                           |
| Researcher | Why was it being ignored? Did it not affect the result?                                                      |
| Participant| Yes, just like that ignoring 20 kg is correct.                                                               |
| Researcher | So you didn't think it would affect the result?                                                             |
| Participant| Yes, madam.                                                                                                  |
| Researcher | Lets see point b) did you know what the meaning of question?                                                 |
| Participant| Asking the minimum number to transport 408 boxes?                                                            |
| Researcher | Try reading the command again.                                                                               |
| Participant| (reading questions aloud and repeatedly)                                                                    |
| Researcher | Do you have a different understanding or still the same?                                                    |
| Participant| Yes, it still the same.                                                                                      |
| Researcher | In problem 2, what is the question?                                                                          |
| Participant| Speed of the motorcycle.                                                                                     |
| Researcher | Do you think the word speed and minimum speed is the same?                                                  |
| Participant| I'm not sure, but it seems the same thing.                                                                    |
| Researcher | Why did you write "50-15" in the end of your answer?                                                          |
| Participant| Because the motorcycle need to be repaired, so it before the final answer it was being reduced by 15 minutes. |
Through the results of the interview, participants had difficulty determining the steps to work correctly. In problem 1, the participant mistakenly understood the problem. Participant considered that the maximum transportation limit of 1500 was also applying to settle point b). Likewise problem 2, the answer of the speed was being reduction with time, even though it wasn’t the correct concept. The students have not sufficiently assimilated the concept of inequality to justify the answer. Supported data in Figure 3, only 47% participants who could apply the obtained concept and procedure well. So applying obtained concepts and procedure aspect need to be considered.

3.3. Expanding mathematical ideas aspect

Figure 5. Diagram of expanding mathematical ideas aspect

Figure 5 shows that in the Expanding Mathematical ideas aspect, 60% of participants don’t able to connect between mathematical concept and mathematics with other disciplines also daily activities. Only 7% of participants were very good to relate mathematical concepts and connect mathematics with other disciplines and daily activities. The next picture results from the participants' worksheet that were seen from the aspects of Expanding Mathematical ideas.

Figure 6. One of the participant’s worksheet in expanding mathematical ideas ((a) Problem 1, (b) Problem 2)

Figure 6 showed the participant can connect mathematics with other disciplines and daily activities, but with the wrong ideas and concepts. Next conversation was the interview with participant regarding aspects of expanding mathematical ideas.
Researcher : Have you ever seen and watched a car, bus or truck with too much load?
Participant : Yes, madam. When I ride a motorcycle, then face a truck with a lot of cargo. I'm afraid to overtake.
Researcher : Have you ever seen a truck that crashed or broke down because of overload?
Participant : Yes, madam, there was a truck that fell while transporting wood.
Researcher : Is there a relation between the incident and Problem 1?
Participant : There is, it is discussing a car load.
Researcher : Is there anything else, maybe something more specific?
Participant : That's all madam.
Researcher : OK, now move on to Problem 2. Where did you get s, t, and v notation from?
Participant : It is from physics; we were just learning the material. s represents distance, t represents time and v represents speed.
Researcher : Have you ever been late for school because of a broken vehicle or a flat tire?
Participant : No madam, I’m riding a bus.
Researcher : Imagine that you need to repair the vehicle before you go to school. Does it mean the time to get to school is longer or faster?
Participant : Faster mom
Researcher : Try to pay attention again?
Participant : (silent and think for some time) I don’t know madam

Associated with the ability to connect mathematics with other disciplines. Participants could recognize the problem and take steps to solve it. But in connecting formulas and the application of concepts from other disciplines learning still experienced error.

You can see three aspects of the mathematical connection skill of the participants in Figure 7.

![Figure 7. Diagram of mathematical connection skill](image)

Based on Figure 7, the highest frequency is being showed in left side. Modeling problem aspects amounted to 9 participants, aspects of applying obtained concepts and procedures amounted to 8 participants, and aspects of expanding mathematical ideas amounted to 9 participants. Therefore, it can be generalized to Pie Chart (right) 54% of participants have low mathematical connection skill. So the mathematical connections skill in Boyolali senior high school is still relatively low.

4. Discussion
We conducted this research to determine the mathematical connection skills of senior high school students in Boyolali on the contextual problems of linear inequality material. The result of research on aspects of modeling the problem, participants run into difficulty understanding the problem and planning a solution. In line with the research of Jha [8], Prakitipong and Nakamura [9] also Santoso, et.al [10] most students made mistakes in understanding problems when solving math problems. Research conducted by In'am [11]. Some students did not understand the problem well, despite carrying out the plan of resolution. The stage of organizing the right notation to solve a problem and
planning a solution is not clearly arranged. So that things that want to be achieved by participants can not be seen properly. Under the research of Dewi and Kusrini\(^7\) that students experience procedural errors, namely errors in writing symbols about what is being asked.

For the aspect of applying obtained concept and procedure, 53% of participants had difficulty using the right concept in solving contextual problems and did not complete the answering procedure so that the participant did not answer what it asked. Under Rahayuningsih and Qohar\(^{[12]}\) research in the process ability stage, students do not do the mathematical stages and wrong in manipulating variables. It also happened in the research of Dewi and Kusrini\(^{[13]}\). Students made a mistake by not continuing the completion process that they had compiled so that students did not get the final answer. The result shows contextual problems are not an easy thing to solve. In line with the opinion of Boaler\(^{[14]}\) and Carraher & Schliemann\(^{[15]}\) that contextual problems do not make mathematics easier to understand and motivate students.

In the aspect of Expanding Mathematical ideas, 60% of participants have difficulty developing mathematical ideas. Under Widjaja\(^{[16]}\) needed explicit links between the context and the mathematics ideas to support students’ progression in their mathematical thinking. Even though most participants experienced difficulties, there were 7% of participants able to develop mathematical ideas very well. This is in line with research conducted by Rangkuti\(^{[17]}\) the students’ mathematical connection activity on solving the questions showed that there is a distinction between a student and another student. There are some finding about the method of solving the questions the students uses which according to their learning experience.

Based on the general result of the study that the skills of participants’ mathematical connections by 54% poorly, 33% good and 13% very good. Through these results showed that mathematical connections skills in Boyolali senior high school at contextual problems is still low.

5. Conclusion
Learning mathematics is generally seen as several topics so that each topic is taught separately. This makes students remember many concepts and do not recognize general principles relevant to various fields. Therefore, learning must help students to see how mathematical ideas it interrelates. When mathematical ideas are associated with daily experiences, students will surely appreciate the usefulness of mathematics. In contextual problems, we require students not only to master the concepts and procedures of work, but thoroughly from problem modeling to the development of mathematical ideas to interpret the results of calculations into desired answers. The result show that students’ mathematical connection skills were still low. We saw this that students were unable in modeling the contextual problems correctly, students could not apply the obtained concepts and procedures also getting difficulty in expanding mathematical ideas. Therefore, the next researcher can conduct research on how to improve students' mathematical connection skills by using various learning models related to contextual problems.

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