Analysis of Students' Mathematical Problem-Solving Ability Based on John Dewey's Theory

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Abstract

Problem-solving ability is one of the important abilities to find out how far students use their knowledge and thinking skills. In this study, we will be seen students' problem-solving abilities based on John Dewey's problem-solving steps. In the third step of problem-solving according to John Dewey, students can see possible strategies that can be used in the problem-solving process and then test these possibilities until finding the best solution from the possible problem-solving strategies that have been developed. The purpose of this study was to describe students' mathematical problem-solving abilities using problem-solving steps based on John Dewey's Theory. This research is descriptive qualitative research carried out in class X SMA Negeri 8 Pontianak Academic Year 2020/2021. The selection of the subjects used the purposive random sampling technique. The instruments used in this study were problem-solving ability tests and interviews. Furthermore, the data analysis techniques were data reduction, data presentation, and data conclusion. Three student answers were selected to see students' mathematical problem-solving abilities based on problem-solving steps of John Dewey's Theory and several conclusions obtained. From this research, it can be concluded that the students who used problem-solving steps based on John Dewey's theory were able to develop several problem-solving hypotheses. According to John Dewey, the use of problem-solving steps has tends to improve students' problem-solving abilities because they have steps to develop hypotheses or possibilities for problem-solving.

Keywords
Problem Solving Ability, John Dewey's Theory, Systems of Linear Equations

1. Introduction

In learning mathematics, a problem can be said to be a mathematical problem if the problem is solved using proper procedures or rules in mathematics. The importance of problem solving skills in mathematics has been written in the (Ministry of National Education, 2006) that one of the objectives of learning mathematics is to solve problems including the ability to understand problems, design mathematical models, solve models, and interpret the obtained solutions. The book (National Council of Teachers of Mathematics, 2000) states that there are five basic mathematical abilities, which each of which has its own standard, including Problem Solving, Reasoning and Proof, Communication, Connections, and Representation. One of the abilities that students must have is the ability to solve problems (Problem Solving). According to (National Council of Teachers of Mathematics, 2000), problem solving ability means being involved in a task that the solution is unknown, to find the solution students must make use of the knowledge they have. In addition, based on the opinion of (Moneva et al., 2020), problem-solving ability are students' ability to solve problems by thinking critically to find the right solution to solve the problem. Based on those two opinions, it can be concluded that problem solving ability in the context of learning are students' ability in critical thinking using knowledge to find the right solution of a given problem.

The ability to solve problems is one of the important abilities that students have. It is because by knowing the capacity of the student's problem-solving abilities, the teacher can measure the extent of students' thinking processes in finding solutions and solving the problems. The importance of problem-solving abilities that students must have is also stated by (Khalid et al., 2020) that problem solving ability is one of the important skills of the 21st century that students must have because it has many advantages that will be enjoyed by a problem solver in everyday life. This statement is also in line with the results of research conducted by (Güleç, 2020) that the problem-solving ability will determine the role of individuals in solving problems in their environment. The importance of problem-solving skills can also be

seen from the Program for International Student Assessment (PISA) which prioritizes how students take steps and think in solving problems in the fields of mathematics, science, and literacy. In learning mathematics, problem solving ability is one of the important abilities to find out how far students use their knowledge and thinking skills to be used in solving routine and non-routine mathematics problems in everyday life.

As one of the important mathematical abilities that students must have, the ability to solve a mathematical problem naturally has criteria and indicators in the process of achieving mathematical ability. (Vizioli & Kaminski, 2017) state that to introduce the concept of problem solving to students, it can be focused on the exercises of interpreting procedures or sequences in problem solving activities. In this study, it will be seen that students' problem-solving abilities based on John Dewey's problem-solving steps. In the third step of problem solving according to John Dewey, students can see possible strategies that can be used in the problem-solving process, and then test these possibilities until finding the best solution from the possible problem-solving strategies that have been developed. It allows students to develop their problem-solving abilities because they are able to develop several hypotheses and then select the best hypothesis to be used in problem solving. The selection of the best hypothesis from the hypotheses that has been developed in the problem solving process is also in line with the theory of (Kim et al., 2018) that to solve problems and improve problem solving ability, students must adopt the best suited method to the problem. Selecting the hypothesis is very essential because from time to time the problems given by the teacher may be different even though the context of the material being taught is still the same. Thus, selecting the best hypothesis from the hypotheses to solve the problem can improve the students' problem-solving ability to solve various problems.

2. Literature Review

2.1 Problem Solving Ability

Problems arise when someone will achieve a goal but have obstacles in achieving that goal. This statement is also in accordance with the opinion of (Hoosain, 2004) that a problem is a first time experience of an individual so that there is no known procedure to handle it. From a problem, a way arises to achieve the desired goal and then which is called problem solving. Basically, every human being will experience problems and can solve them. This theory is in accordance with the opinion of (Ohlsson, 2012) that the ability to solve unusual problems has played a central role in human history through technological innovation or other means. (Annamalai et al., 2013) argue that solving a problem is a complex process whose skills and stages can only be known well by us. It shows that since a long time ago every human being must have the capacity to solve problems within him. A person is said to have good problem-solving ability if he is able to solve the problems given to him. According to (Mienaltowski, 2011), the success in solving one's problems can be defined if a person can provide a single solution of a problem or the number of solutions offered by the individual in solving the problem.

Although, in fact, every human being has natural abilities to solve problems, this ability must always be sharpened and directed so that each individual can solve the problems he faces more effectively. It is the basis of why problem solving is always taught in the world of education. Basically, in education, an individual will be directed to process relevant information and knowledge as well as the ability to reason in order to solve problems as needed (Ogunleye, 2009). It is also conveyed by (Aydoğdu & Ayaz, 2008) that problem solving has a broader purpose because the purpose of education is to provide children the skills to solve problems. In the field of mathematics, problem solving ability is one of the basic skills that students must possess (National Council of Teachers of Mathematics, 2000). The main objective in teaching problem solving skills in mathematics is so that students can develop generic abilities and be able to use mathematics in solving real life problems (Gurat, 2018). "Real Problem Solving" allows students to practice math skills or learn new skills, using mathematics as a tool to solve problems (Aydoğdu & Ayaz, 2008). In other words, in learning mathematics, an individual will be taught to be able to use mathematics so that it can be used as relevant information to solve problems in everyday life.

In an effort to improve problem-solving abilities for students, of course, it does not always go well. There are many obstacles that make students usually do not have well categorized problem solving skills. (Yu et al., 2015) argue that the inability of students to solve problems outside the classroom is because they do not have the opportunity to solve problems and apply appropriate knowledge in the context of real life. This obstacle is one of the factors that students consider mathematics to be a difficult subject at school. This is in line with the results of research conducted by (Muttaqi et al., 2021) that mathematics is a difficult subject for students. The students find it difficult to complete the

mathematics exercises given. The problems can be solved by analyzing the mistakes made by students in the mathematics learning process. Thus, later, a solution will be given to at least minimize the students' mistakes in the problem-solving process.

2.2 John Dewey's Problem-Solving Steps

John Dewey is a philosopher and educator who comes from America. Many of Dewey's thoughts have influenced the world of education. John Dewey argues that education will be most effective if the content in education allows students to be able to collect all available information to deepen the possibility of solving the problems given (Talebi, 2016). According to Dewey, learning process allows students to have freedom of thought, judgment, and freedom to make decisions (Sikandar, 2015). John Dewey and his theory of problem solving emphasize the possibilities in selecting the best solution or what we can call a hypothesis.

The problem solving steps based on John Dewey quoted from (Carson, 2007) are 1) Confront problem, 2) Diagnose or Define Problem, 3) Inventory Several Solutions, 4) Conjecture Consequences of Solution, 5) Test Consequences. The first step of problem solving based on John Dewey is Confront Problem. Students are asked to be able to identify or present the problem. According to (Mamona-Downs & Downs, 2005), the more things that are identified, the more things that can be done. In addition, (Reiter-Palmon & Robinson, 2009) state that because the process of identifying and presenting a problem has an important influence on creativity, the involvement of this step in problem solving is an important process. In dealing with the problems given, it is necessary to give specific attention to the problem. If students can identify the problems well, then students can identify the difficulties they face to solve the problems given.

The next step in problem solving based on John Dewey is to define the problem. Problem definition is done by diagnosing the problem to determine the possible number of solutions. (Rasch, 2014) states that classifying data based on its various elements will help to determine what type of problem a person is facing. Furthermore, (Carson, 2007) states that the second step in problem solving is when someone looks for patterns or attempts to determine the concepts or principles that play a role in the problem. The step of defining the problem can be done by classifying what is known in the problem which is a guide in solving the problem. The third step is the Inventory Several Solutions. In this step, students can collect various possible data as supporting material in problem solving. It is also supported by (Carson, 2007) who reveals that the finding of several possible problem solving about how students solve problems based on what students have found in steps one and two. In this step, students can analyze and identify possible patterns of problem solving. John Dewey believes that every child has unique ability in problem-solving thinking.

Therefore, the habituation of developing hypotheses will make students learn to develop their own thinking results, not limited to just following the example modeled by the teacher. (Achkovska Leshkovska & Miovska Spaseva, 2016) argue that this step will increase students' curiosity and confidence in determining direction when solving problems. This third step is what differentiates John Dewey's theory of problem solving from the others' because students are given the opportunity to develop ideas and determine the methods they use in solving the problems given. The fourth step is Conjecture Consequence of Solution. After making a plan for the solution that will be used, students will decide what solutions will be used based on the plans and hypotheses that have been made. In this step, students freely use the problem solving design. It provides a positive aspect of their learning experience, because even though in the learning process students make mistakes, it will become an experience for the next learning process (Sikandar, 2015). The process of determining the solution used by students based on the problem-solving design they have previously made will surely increase the level of student confidence. Besides, even though the design made has errors, it can be used as a reflection so that the same mistakes are not repeated in the next learning process. The final step in this problem-solving step is the test consequences (Shofwan et al. 2021). At this stage, students will test whether the problem-solving process carried out is in accordance with the problem requested. In this step, it will also allow students to correct it if there are mistakes made in the problem solving process.

3. Methods

This research is a descriptive qualitative research. This research was conducted at SMA Negeri 8 Pontianak City. The research subjects were students of class X in the academic year of 2020/2021. The researcher gave the students the problem-solving ability test questions on the Three Variable Linear Equation System material to the students.

The test questions given are questions of essay type. After the test has been completed, the next step the researcher takes is to analyze the answers have been completed by the students. After analyzing the answers that had been completed by the students, then three students were selected to be interviewed about the answers they had completed in the test. The subjects were selected using purposive random sampling technique. In selecting the subject, paying attention to several things, namely the answers presented by students in answering the problem-solving ability test on the Three Variable Linear Equation System material. Furthermore, mathematics teacher's coordination was concerned in selecting the subjects. After the interviews were conducted with three research subjects, the results of the study were then validated using data triangulation techiques.

4. Data Collection

The main instrument in this study is the researcher. To support the research instrument, the following instruments and techniques were also used in collecting the data, as following. Problem solving skills test. The problem-solving ability test given was a problem-solving ability test on the Three Variable Linear Equation System material. Furthermore, the test was given to all students of class X IPS 3 at SMA Negeri 8 Pontianak to determine the students' mathematical problem solving abilities. Interview. After the test was done, three students were randomly selected to be interviewed about the tests that had been done. The test answers were used by researchers as a reference in conducting interviews. The purpose of this interview was to determine and check every step of the problem-solving ability based on John Dewey's theory. Because this research was conducted during the COVID-19 pandemic, interviews were conducted online.

Then, to analyze the data obtained, it used data reduction, data presentation, and data conclusions and also to obtain the validity of the data, triangulation techniques were used. Triangulation is a technique of checking information and data with different techniques but from the same source. The data obtained in this study were tests of students 'problem-solving abilities on the material of Three Variable Linear Equation Systems and interviews which were conducted with the aim of knowing students' problem-solving abilities using steps of problem-solving abilities based on John Dewey.

5. Results and Discussion

In collecting the data to measure students' mathematical problem-solving abilities, a problem-solving ability test was used on the material of Three Variable Linear Equation Systems in class X SMA Negeri 8 Pontianak. The problems that must be solved by students in the test are as follows.

There are three numbers a, b, and c. The average of the three numbers is equal to 16. The second number plus 20 is the same as the other numbers. The third number is the same as the other numbers minus 4. What are the numbers referred?

Then, to see students' mathematical problem-solving abilities based on problem-solving steps of John Dewey's Theory, three student answers were selected. The three answers had differences in the problem-solving stages carried out by the students. Based on the answers chosen, the next step is to interview students based on the answers they worked on. Students' answers were used as a benchmark in interviews with the students to determine their mathematical problem-solving abilities based on problem-solving steps of John Dewey's theory.

The first chosen answer was the students' answer with high problem solving ability category based on John Dewey's Theory. Student 1's answer is presented in Figure 1 as follows.

The handwritten answer sheet with its translation table:

Translation

Noted that: 3 numbers a, b, c
with a = first number
  b = second number
  c = third number
Average = $\overline{X} = 16$
Statistics

$$\overline{X} = \frac{a+b+c}{3}$$

$$16 = \frac{a+b+c}{3}$$

$$\frac{a+b+c}{3} = 16 \ ...(1)$$

$b + 20 = a + c$
$b = a + c - 20 \ ... (2)$

$c = a + b - 4 \ ... (3)$

Answer
Substitution (2) into (3)
$c = a + b - 4$
$c = a + (a + c - 20) - 4$
$2a = 24$
$a = 12$

Substitution a = 12 into (3)
$c = a + b - 4$
$c = 12 + b - 4$
$c = 8 + b \ ... (4)$
Substitution a = 12 and (4)
into equation (1)
$$\frac{a+b+c}{3} = 16$$
$a + b + c = 48$
$12 + b + 8 + b = 48$
$2b + 20 = 48$
$2b = 28$
$b = 14$
Substitution a = 12 and
b = 14 into (3)
$c = a + b - 4$
$c = 12 + 14 - 4$
$c = 22$

Then, the value of the number in queation are
$a = 12;$ $b = 14$;
$c = 22$

Figure 1. Student 1's answers (A1) in solving Three Variable Linear Equation Systems questions

The results of interviews conducted by researchers (Q) with Student 1 (A1) are as follows.

Q   : From that question, can you explain the problem what's in the question?
A1   : Yes, from that question, there were three numbers, but the three values are not known yet, we were asked to find what is the value of each number?
Q   : From the question, what things do you know?
A1   : From the question I can see that three equations can be formed from the three sentences contained in the question.
Q   : Good. Can you explain which sentences you can turn into the three equations?
A1   : As you can see in my answer sheet, for the first sentence that can be changed, namely the average of the three numbers is equal to 16, I changed the sentence be the first equation, namely $\frac{a+b+c}{3} = 16$. Then, in the second sentence, namely the second number plus 20 is the same as the other number, so I changed to $b + 20 = a + c$, and the third sentence is the third number is the same as the other number minus four $c = a + b - 4$.
Q   : Okay, next, you answered earlier that you changed $+20 = a + c$, but why did you change the answer sheet to $b + 20 = a + c$ $b = a + c - 20$?
A1   : The reason is so that the equation looks simpler, so I find it easier to see the form of the equation, because I am more focused on the second and third equations which have a simpler form.
Q   : When answering the question, in the first step, can you explain, why do you substitute the second equation to the third equation, because you can substitute the second equation to the first equation, or the third equation to the first equation, right?
A1   : I had time to substitute the second equation to the first equation then the third equation to the first equation, but it was too complicated, so I preferred to substitute equation 2 to equation 3 because both equations were simpler and in one step, I succeeded in finding the value of a as requested in the question.

From the results of the interviews conducted, it was found that Student 1 (A1) mathematical problem-solving abilities based on the problem-solving steps of John Dewey are as follows in Table 1.

Table 1. Problem Solving Ability Based on Interview Results with Students 1

Steps to Solve Problems According to John Dewey	Problem Solving by Students
Confront Problem	Student 1 could present the problem well. It was obtained from the results of the interview that student 1 could recognize the problem contained in the questions
Define Problem	Student 1 was able to recognize what are the important points to help him to solve the problems and what problems must be solved on these problems
Inventory Several Solution	Student 1 could develop several hypotheses. It was obtained from students' answers which revealed that he could see the possibilities for solving the problem of the three equations he found.
Conjecture Consequence of Solution	To find out some of the previously developed hypotheses, Student 1 conducted a test by substituting the second equation to the first equation, substituting the third equation to the first equation, and substituting the second equation to the third equation.
Test Consequences	Because substituting the second equation to the first equation and substituting the third equation for the first equation is considered too complicated, Student 1 decided to use the best hypothesis according to him, namely substituting the second equation to the third equation.

Based on the results of Student 1's answer analysis in Figure 1 and the results of the interview analysis presented in Table 1, it was found that Student 1 had high category of problem-solving ability because the student could fulfill all problem solving steps based on John Dewey's theory which is presented in Table 1.

Furthermore, the second chosen answer was the student's answer with the category of moderate problem-solving ability based on John Dewey's Theory. Student 2's answer is presented in Figure 2 as follows.

Translation

Noted that : 3 numbers namely a, b, c have an average value of 16 $\text{Average} = \dfrac{\text{the amount of all data}}{\text{lots of data}}$ $\overline{X} = \dfrac{a+b+c}{3}$ $16 = \dfrac{a+b+c}{3}$ $48 = a+b+c$ $a+b+c = 48 \ldots (I)$ $b + 20 = a + c$ $a - b + c = 20 \ldots (II)$ $c = a + b - 4$ $a + b - c = 4 \ldots (III)$ Question: the numbers in question? Answer Elimination equation (I) and equation (II) $a + b + c = 48$ $a - b + c = 20$ $\underline{\hspace{3cm}} +$ $2a + 2c = 68 \ldots (IV)$	Elimination equation (I) and equation (III) $a + b + c = 48$ $a + b - c = 4$ $\underline{\hspace{3cm}} -$ $2c = 44$ $c = 22$ Substitution $c = 22$ into equation (IV) $2a + 2c = 68$ $2a + 2(22) = 68$ $2a + 44 = 68$ $2a = 24$ $a = 12$ Substitution $a = 12$ and $c = 22$ into equation (I) $a + b + c = 48$ $12 + b + 22 = 48$ $34 + b = 48$ $b = 14$ Obtained $c = 22 \, ; \, a = 12 \, ; \, b = 14$

Figure 2. Student 2's answers (A2) in solving Three Variable Linear Equation Systems questions

The results of the interviews conducted by the researcher (Q) with Student 2 (A2) are as follows.

Q : From this question, can you explain what problem is in the problem?
A2 : Yes, there are three unknown numbers, and we are asked to find the value of those numbers
Q : From the questions, what things do you know?
A2 : First, the average of the three numbers is equal to 16, then the second number plus 20 is equal to the other numbers, and the third number is equal to the other numbers minus 4.
Q : Well then, in the answer sheet that you wrote, why did you put these three equations variables $a, b,$ and c and move it to the left side of the equal mark?
A2 : Yes, because usually the problems I work on from the examples given are all like that, all variables are on the left side of the equal mark
Q : Then, why did you eliminate the first equation and the second equation?
A2 : Because usually in explaining sample questions, the teacher eliminates equation 1 and equation 2 first.
Q : Did you think about substituting the second equation to the third equation?
A2 : No, because usually teachers use ways of elimination first
Q : What if the question is replaced, and you still follow the steps your teacher usually does, but it will make you run out of time because the steps are too long. What would you do?
A2 : Ah yes, but is possible? I think the example given by the teacher by eliminating the first and the second equations is the fastest step.
Q : Do you realize, in the drawing conclusions, there was a little mistake that you did?
A2 : Ah right, I should have written the values of these numbers in order.

From the results of the interviews conducted, it was found that Student 2 (A2)'s mathematical problem-solving abilities based on the problem-solving steps of John Dewey are as follows in Table 2.

Table 2. Problem Solving Ability Based on Interview Results with Students 2

Steps to Solve Problems According to John Dewey	Problem Solving by Students
Confront Problem	Student 2 could present the problem well. It was obtained from the results of the interview that Student 2 could recognize the problem contained in the questions
Define Problem	Student 2 was able to recognize what were the important points to help him to solve the problem, but Student 2 was still based on the example questions that the teacher usually gave in changing the form of the equation
Inventory Several Solution	Student 2 could not develop possible ways to solve the problem
Conjecture Consequence of Solution	Due to not being able to develop some possible problem solving, Student 2 did not conduct hypothesis testing in problem solving.
Test Consequences	Student 2 did not select the best hypothesis, because in solving the problem it was still based on the method given by the teacher. In addition, there was a slight error in Student 2 in drawing conclusions from the questions.

Based on the results of Student 2's answer analysis in Figure 2 and the results of the interview analysis presented in Table 2, it was found that Student 2 was able to complete the questions, but the completion steps were still pegged to the method given by the teacher, so student had not been able to present several possible ways of solving the problem. Based on the analysis of problem solving presented in Table 2, Student 2 had not fulfilled the stage of the Inventory Several Solution problem solving based on the problem solving steps of John Dewey's Theory. If students rely on the method given by the teacher without developing their thinking skills in solving problems, students will not be able to solve the problems properly because every problem always has different solution steps.

Furthermore, the third chosen answer is the answer of students with low problem solving ability based on John Dewey's Theory. Student 3's answer is presented in Figure 3 as follows.

Figure 3. Students' answers 3 (A3) in solving Three Variable Linear Equation Systems questions

Q   : From this question, can you explain what problem is in the question?
A3   : Three numbers $a, b,$ and c were unknown then we were asked to find the value of those numbers
Q   : Then, why is there a question mark on the answer sheet on the average?
A3   : Yes, I can understand two sentences after the average sentence contained in the problem, but I cannot interpret the function and the meaning of the sentence from the average number is 16.

Q   : What made you confused by this sentence? As for the other sentences you can understand them well.
A3   : Because during the class the teacher never gave an example with the average sentence contained in the
            questions, so I was confused about the relationship between the numbers and the average
Q   : But even if you don't understand, you managed to find the value of the numbers?
A3   : Yes, because there is no other option than the second and third equation. I tried to find the answer, even
though I only got the value of a, because after this I could not understand and find the value of b and c

From the results of the interviews conducted, it was found that Student 3 (A3) mathematical problem-solving abilities based on the problem-solving steps of John Dewey are as follows in Table 3.

Table 3. Problem Solving Ability Based on Interview Results with Students 3

Steps to Solve Problems According to John Dewey	Problem Solving done by Students
Confront Problem	Student 3 could present the problem well. It was obtained from the results of the interview that Student 3 could recognize the problem contained in the questions
Define Problem	Student 3 was only able to recognize two important points which were the guidance in solving the question. Student 3 had not been able to define the relationship between the first clue in the question to solve the problem.
Inventory Several Solution	Student 3 could not develop possible ways that could be used to solve the problem because he could not define the problem.
Conjecture Consequence of Solution	Due to not being able to develop several possible solutions to problems, Student 3 did not conduct hypothesis testing in problem solving.
Test Consequences	Student 3 could not choose the best solution because he was unable to define the problem. It resulted in Student 3's inability to solve the given problem.

Based on the results of Student 3's answer analysis in Figure 3 and the results of the interview analysis presented in Table 3, it was found that Student 3 was only able to perform the first problem solving step, the Confront Problem, and did not fulfill the other problem solving steps based on the problem solving steps of John Dewey's theory. Based on Student 3's answer in Figure 3, Student 3 was only able to mention two important things that could be used in solving the problem, so Student 3 had not even been able to fulfill the Define Problem steps based on the John Dewey's Theory in table 3. The interview's results revealed that it happened because Student 3 never worked on similar types of questions during the learning process. Based on this, Student 3 is categorized as having low problem solving ability based on John Dewey's Theory because Student 3 is only able to recognize the problems contained in the questions without being able to solve the given problems.

6. Conclusion

From the results and discussions, several conclusions are obtained, namely, student 1 who can do all the problem-solving steps based on John Dewey's theory, can solve the problem well. Student 1 does not only depend on the solving steps presented by the teacher so that he has a tendency to develop his mathematical problem-solving abilities because he can see several possibilities or ways of taking problem solving steps. Student 2 did not undertake the stages of developing several hypotheses in the problem-solving step according to John Dewey's Theory but was able to solve the problem but was less precise in drawing the conclusions. Although it can solve the given problem well, Student 2 still depends on the example of problem solving presented by the teacher, it is feared that they will not be able to develop their mathematical problem-solving skills, because not all problem solving have the same steps. Student 3 could present or recognize the problem contained in the test questions, but Student 3 could not define the problem because he could not change the sentence into a mathematical model. As a result, Student 3 could not complete the given test questions. According to John Dewey, the use of problem-solving steps has a tendency to improve students' problem-solving abilities because they have steps to develop hypotheses or possibilities for problem solving.

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