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The Influence Of Mathematical Modeling Learning Towards Complex Problem Solving

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Abstract. Complex problem solving (CPS) as a new paradigm in solving problems is one often he the ten soft skills that need to be possessed in facing the Industrial Revolution 4.0 and even becomes essential because it ranks at the top of the list of job requirements in the 21st century. The CPS indicators include (1) collecting information systematically, (2) diagnosing problems by integrating the most relevant information, (3) finding potential solutions by building an appropriate model of the problem structure, and (4) determining solutions and implementing them. Mathematical modeling as a model of teaching mathematics aims to read, interpret, formulate and solve specific problems. The steps of learning Mathematical modeling consist of the identification stage, the stage of determining the mathematical model, the stage of determining the solution of the model, and the interpretation of the model solution. This study aimed to examine the effect of mathematical modeling learning on CPS. This study uses a test technique with data analysis techniques paired sample t-test. The results showed an effect of Mathematical modeling learning on CPS, which was indicated by the difference in the CPS abilities of elementary school teacher candidates before and after mathematical modeling learning. From the results of the SPSS test, the value of sig. (2-tailed): 0.000 < 0.005 on the paired sample t-test results so that Ha is accepted, meaning there are differences in CPS before and after mathematical modeling learning. Mathematical modeling learning has a role in helping elementary school teacher candidates to solve complex problems.

Key words: mathematical modeling learning, complex problem solving, mathematics learning

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INTRODUCTION

In the Indonesian mathematics curriculum, problem solving is listed as one of its goals (Suraji, Maimunah, and Saragih 2017). Problem solving is also a 21st century ability in addition to critical thinking, creativity, metacognition, communication, debating, collaborating, digital literacy, and technological literacy (Haviz and Maris 2020; Binkley et al, 2018). Problem solving ability is also a very important mathematical ability for students and teachers from basic education to higher education (Suraji et al. 2017). In the NCTM (National Council of Teacher of Mathematics) mathematical thinking consists of mathematical understanding, mathematical reasoning, mathematical connections, mathematical communication, mathematical representation and problem solving (Suraji et al. 2017). In solving the problem there are several steps used, namely understanding the problem, making plans, solving problems and checking again (Klerlein and Hervey 2019) which is better known as heuristics or Polya steps (Cahyati and Kharisudin 2020). Problems as a situation that cannot be solved immediately or routinely become one of the most complex aspects for humans (OECD 2012). In solving problems, it begins with awareness of differences in reality and expectations or realizing a problem, understanding the nature of the problem, planning what strategy to use, using a planned strategy to find a solution and re-examining the results of the settlement whether it is correct or not (Suraji et al. 2017; Klerlein and Hervey 2019; Cahyati and Kharisudin 2020). Mathematical problem solving ability can be used as a basic capital in solving complex problems. Problem solving skills develop not only to solve simple problems but also to complex problems. Complex problem solving (CPS) as a new paradigm in solving problems is one of the 10 soft skills that need to be possessed in facing the Industrial Revolution 4.0 and even becomes very important because it ranks at the top of the list of job requirements in the 21st century (Eseryel et al., 2013; Eichmann et al., 2019). The 10 main competencies needed by a professional are complex problem solving, critical thinking, creativity, people management, coordinating with others, emotional intelligence, judgments and decision making, service orientation, megitiation, and cognitive flexibility (Gleason, 2018; WEF, 2016; E. Mahendra, 2019; Sulastri et al., 2019; Asfar & Sulastri, 2021). Complex problem solving (CPS) is very

important as the ability to formulate problems and make the right decisions in urgent, challenging, and complex situations (Eichmann et al., 2019). Seeing the importance of CPS skills, it is necessary to be trained as early as possible even at the basic level. To be able to achieve this, the role of elementary school teachers is needed. PGSD students as prospective elementary school teachers are certainly highly recommended to have good CPS skills.

Problem solving problems are often presented related to real life, because involving real problems makes mathematics more meaningful (Khusna and Ulfah 2021). In understanding the problem, students must have the ability to translate the problem well. In the process of translating the problem, later the problem should be understood correctly. To achieve this, assistance is needed, one of which can be in the form of a learning model. Mathematical modeling as a learning model is expected to help solve both simple and complex problems. In mathematical modeling, students are able to translate from real world problems or situations into mathematical models (Zulkarnaen 2021). Thus it will help students in determining strategies and solving math problems (Zulkarnaen 2021; Khusna and Ulfah 2021). Modeling is defined as a structured problem representation, both symbolic and verbal (Bahir and Mampouw 2020). Modeling from the basic word model which means a model is a miniature representation of something, a pattern of something to be made, as a representation used to visualize something (Cloutier 2015). Mathematical modeling is an activity that involves the translation of real-world problems or situations into mathematical models in this case students work with the mathematical model and use it to understand problems and solve real-world problems (Jahnke, 2019). Modeling is the process of making a mathematical model which as a result of mathematical modeling is represented in the form of symbols, tables, images or other forms of a problem (Khusna and Ulfah 2021). Thus problem solving is closely related to mathematical modeling (Cahyati and Kharisudin 2020). Problem solving may not always refer to the external world even when it occurs, problem solving usually begins with a real world situation idealized in mathematical terms, and ends with a mathematical result whereas mathematical modeling, starting in the real world, requires formulation of the problem before problem solving, and once the problem is solved, it moves back to the real world where the results are considered in their original context (Pollak 2012). Therefore, it can be said that solving problems can be done through mathematical modeling (Kurniawati and Rosyidi 2019).

Mathematical modeling as a strategy in learning mathematics as done by Cahyati and Kharisudin (2020) in using a mathematical modeling strategy which consists of the identification stage, the stage of determining the mathematical model and determining the relationship between variables and constants, the stage of determining the solution of the model and the stage of interpreting the model solution. . Through learning mathematical modeling, students are directed to think logically, especially when dealing with problem-based math problems (Bahir and Mampouw 2020). Problem solving activities with mathematical modeling are basically a practical and creative process involving a number of stages, all of which require various skills (Edwards and Hamson 1996). Through learning mathematical modeling can help in interpreting complex problem solving with mathematizing activities. It is hoped that mathematical modeling learning models will have an influence on complex problem solving abilities.

Based on observations of some prospective elementary school teachers when solving complex problem solving problems, it appears that they are still confused, students do not understand the complex information conveyed so that the plans prepared are not appropriate. In addition, important relevant information has not been captured properly. In solving complex problems, learning assistance is needed because questions about complex problems are difficult to solve. The learning model of mathematical modeling is thought to be a learning aid in improving complex problem solving abilities.

In a previous study that described the process of student mathematical modeling in solving combination material problems that referred to horizontal and vertical mathematization processes (Meika, Suryadi, and Darhim 2019). Research conducted by (Bahir and Mampouw 2020) on the analysis of high school students' errors in making mathematical modeling and their causal factors. Research conducted by (Kharisudin and Cahyati 2020) on the effectiveness of problem-solving skills using mathematical modeling strategies in MEA and describing problem-solving skills based on self-concept. This research is different from previous research because it will examine and explore the

influence of mathematical modeling learning on complex problem solving in elementary school teacher candidates. This research is expected to obtain data on complex problem solving abilities or CPS for elementary school teacher candidates before and after learning with mathematical models, data on problem solving abilities for elementary school teachers, and test results on the effect of mathematical modeling on problem solving for elementary school teachers.

METHODS

This research uses a non-experimental quantitative design as has been done by Pramawaty, N., & Hartati, E. (2012) with a pretest posttest design study. The researcher also used a descriptive approach to analyze the answer sheets. In the pre-study, an initial interview was conducted as a preliminary study related to CPS. The study used technical tests in the form of description questions and answer sheet documentation. The research subjects were 42 students of the Elementary School Teacher Education Study Program. The instrument used is the CPS test sheet. Quantitative data were analyzed through normality test and paired sample t test. Before the test questions were given, an expert validation test was given to 3 lecturers and met the valid criteria with suggestions for improvement.

Table 2. Question indicator of CPS

No	Indikator soal	Indikator CPS
1	Presented information on mathematical problems in life about sequences. Some hints are given to solve the problem.	(1) collect information systematically, (2) diagnose problems by integrating the most relevant information, (3) find potential solutions by building appropriate problem structure models, and (4) determine solutions and implement them
2	Presented problems about arithmetic. It is known that someone keeps an animal that has 2 legs and 4 legs and the total number of legs. Students can determine how each animal has 2 legs and 4 legs.	
3	Presented a story about the comparison of the price of an item, students can determine the price of each item.	
4	Presented problems about the shape of the roof of a traditional house (pyramid) with a certain size. The roof of the house will be covered with plastic so it doesn't leak. If it is known the price of plastic material per 1m2 and the available renovation funds. Students can determine the cost needed to cover the roof (pyramid) by connecting knowledge between materials about the surface area of a pyramid, Pythagoras' theorem, and social arithmetic.	

Before the questions were given, the instrument was tested with the following results.

Table 3. Instrument Trial Results

No	Validity	Criteria	Reability	Criteria	TK	Criteria	DB	Criteria
1	0.706	Valid	0.827	Very high	0.708	Easy	0.283	moderate
2	0.571	Valid	0.827	Very high	0.708	Easy	0.261	moderate
3	0.702	Valid	0.827	Very high	0.583	Midle	0.422	Very good
4	0.725	Valid	0.827	Very high	0.292	Hard	0.343	good

Based on table 3, the results of the instrument have met the requirements to be used as a data collection tool. After being declared valid, the test questions were given to PGSD students as prospective elementary school teachers as many as 42 people. Answer sheets were collected and then assessed based on the scoring guidelines and tested based on these data. Student work results are assessed for CPS scores.

RESULTS AND DISCUSSION

After doing the research, the data obtained in the form of data on the ability of CPS. In determining the score is based on giving a score for each indicator. The indicators of CPS ability are (1) collecting information systematically, (2) diagnosing problems by integrating the most relevant information, (3) finding potential solutions by building an appropriate problem structure model, and (4) determining solutions and implementing them. Prior to the t test, the data normality test was carried out, the following results were obtained.

Table 2. Test of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
CPS	.115	42	.184	.960	42	.151

From the data normality test, the results of the mathematical modeling data have a value of sig = 0.200> 0.05 and problem solving data obtained sig = 0.184> 0.05, meaning that the CPS data is normally distributed. After testing the normality of the data, it can be done t which is obtained as follows.

Tabel 3. Output SPSS Uji Paired Sample T-Test

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	pretes - posttest	-14.16279	10.24214	1.56191	-17.31486	-11.01073	-9.068	42	.000

Based on the SPSS output Table 3 above regarding the results of the hypothesis test in the form of a paired sample t-test, it can be seen in the Lower and Upper columns that each has a negative value, namely -17.31486 for Lower and -11.01073 for Upper and the value of sig. (2-tailed): 0.000. This shows that H0 is rejected and for Ha is accepted. So that the results are obtained from the hypothesis that there is a difference in the CPS ability of prospective elementary school teachers between before and after using mathematical modeling learning models.

Based on the results of the study, the results of the t-test with sig 0.000 were obtained. it means that there is a difference in CPS ability before and after learning mathematical modeling. This is because at the stage of mathematical modeling learning models can help students in solving CPS problems. At first, it appears that the average student has difficulty in constructing mental activity independently and formulating an understanding of the problem. And seems to have been able to make mathematical models and then solve them. At the stage of making a mathematical model, the students' ability to interpret, present it in various forms of pictures, tables or schematics. After the test, the researcher tried to conduct an interview on one of the subjects who solved the problem using pattern images. The following is the result of the

completion of one of the subjects.

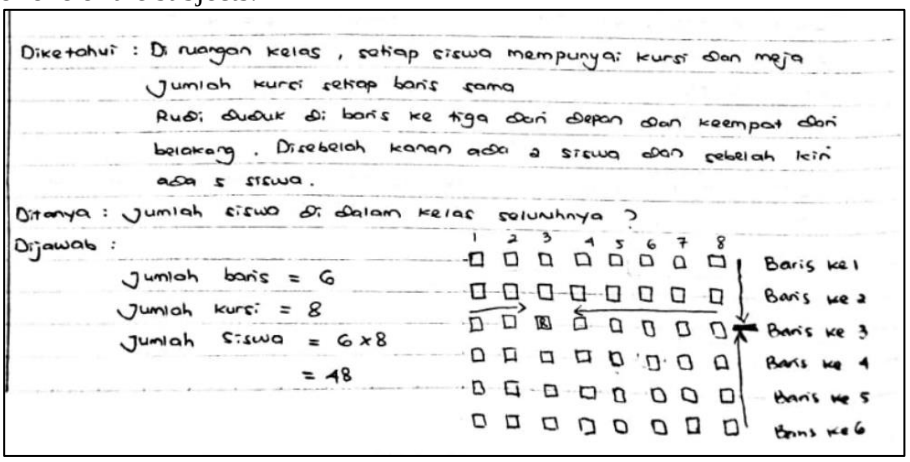

Figure 2. The results of the completion of Subject 1 (S1)

Based on Figure 2 above, it can be seen that the subject completes with the help of pictures. Regarding the indicators of mathematical modeling, the researchers tried to conduct interviews.

Q : How did you solve the problem?
S1 : I try to draw
Q : Do you understand about that?
S1 : Yes, I understand
Q : Are you influenced by other friends' answers?
S1 : No, I can try myself
Q : How do you understand this question?
S1 : At first I was confused, then I tried to read it many times
so I understood it
Q : Why did you choose to draw?
S1 : Because I find it easier to use pictures
Q : Are you sure your answer is correct?
S1 : Yes I'm sure
Q : What makes you sure
S1 : I tried to be careful and looked at the question again and it turned out
to be appropriate

From the results of these interviews, it can be concluded that making pictures is one way in the learning model stage of mathematical modeling, namely mathematization where students can translate specific, simplified real situations into mathematical models (for example, terms, equations, pictures, diagrams, and functions). And it turns out that interpretation in the form of pictures dominates as research conducted by Rellensmann, Schukajlow, and Leopold (2017) that at the interpretation stage of mathematical modeling, students have many ways, one of which can use pictures because drawing strategies are widely used as a powerful tool for motivation in learning. students and problem solving. Based on path analysis shows that strategic knowledge about drawing is positively related to students' modeling performance (Rellensmann et al. 2017).

In the mathematical modeling stage, various types generated by the image learner can be created. The mathematical modeling made by students is very diverse and can also differ from one student to another (Kurniawati and Rosyidi 2019). The type of image according to Rellensmann, Schukajlow, and Leopold (2017) is that mathematical images are abstract images because they provide an external representation of the mathematical model and only describe objects that are relevant to the solution of the problem situation, and are reduced to relevant mathematical features. In mathematical drawings, all objects are reduced to relevant mathematical features such as fire engines, houses, and stairs are reduced to line segments, and their height or length is recorded in the drawing (Rellensmann et al. 2017). In the case of the Subject's work (S1) which is in accordance with Figure 2 above, then the simple image form is included in the mathematical image. In addition to Subject (S1), we present the completion of several subjects.

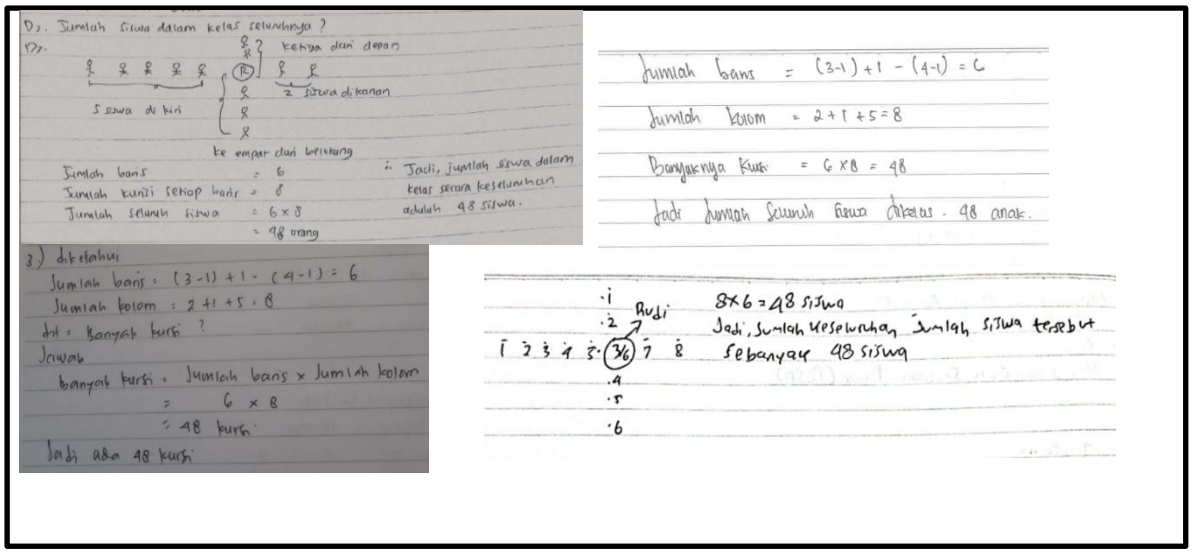

Figure 3. answer sheet

Based on Figure 3, it can be seen how the subject solves the problem in various ways. Some use pictures, patterns, and symbols. This is part of the mathematical modeling ability. And the use of images is one way to mathematize as research (Rellensmann et al. 2017). From the results of the t-test obtained, it is stated that there are differences in students' CPS abilities before and after learning mathematical modeling. Thus, it can be seen that there is an influence of mathematical modeling learning models with CPS, but some subjects say that modeling is difficult because mathematical modeling is the beginning of an understanding of the problem. This is similar to the research conducted by Kurniawati and Rosyidi (2019) which stated that although mathematical modeling is considered difficult for students, not a few students make interpretations of problems in the form of mathematical models independently. Therefore, it takes a lot of practice questions related to mathematical modeling. The same thing can be seen from the results of research from Zulkarnaen (2021) which concludes that students still have difficulty in applying all aspects of the process at the mathematical modeling stage. In addition, the teacher must understand the difficulties of the students, as this will affect the teacher's lesson planning and assessment design. Before the teacher provides learning mathematical modeling, the development of conceptual understanding and procedural understanding as well as students' mathematical reasoning must be checked first. Based on the existing school curriculum, mathematical modeling has not been intensively trained and the curriculum focuses more on problem solving. Whereas mathematical modeling can be used as a way to solve a problem. Students are more familiar with mathematical models than mathematical modeling. And they assume that mathematical modeling is in linear programming material. Even though this is not the case, the knowledge of mathematical modeling that is still low is a problem in itself when solving problem solving problems. Below, we try to show the work of one of the subjects related to geometry, but the subject solves the problem not with pictures, but with mathematical models.

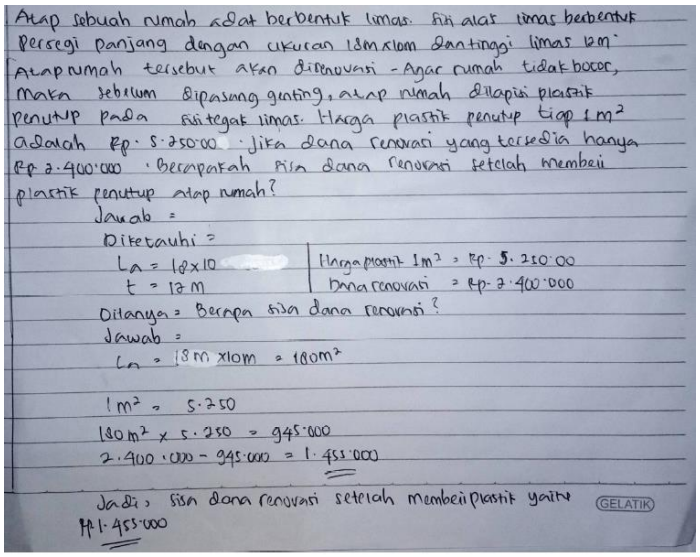

Figure 5. Subject 2 (S2) answer sheet

Based on Figure 5 above, it can be seen that the subject did not finish using the image. The subject uses symbols in the form of variables, but does not seem to understand the problem so that the plan and solution are wrong. The stages of constructing, simplifying, and mathematizing are not yet correct. So to develop mathematical understanding and competence, correct and appropriate mathematical modeling is needed because in CPS students must be able to make formulas and develop mathematical models because mathematical modeling will form mathematical understanding related to the real world with mathematical modeling, they will also be trained in the mathematization process (Meika et al. 2019). Mathematical modeling has many benefits such as the involvement of students according to their interests and understanding, providing its own opportunities and challenges for students and of course this makes students more enthusiastic even though developing mathematical concepts requires teacher guidance every step of the way (Flevares and Schiff 2013).

In the process of representation, mathematical modeling activities provide an advantage because it can stimulate the emergence of social interaction between students in learning mathematics, this can be an interesting discussion space with peers such as when making models, students will construct and practice representing mathematical concepts, data and attributes (Flevares). and Schiff 2013). However, sometimes students often have difficulty in applying the structure consistently or identifying the use of relevant information, of course this really requires the role of the teacher. The scaffolding experience provided by the teacher can guide students in critical thinking, identify relevant characteristics or criteria, collect data through facts and opinions and document data to make choices (Flevares and Schiff 2013).

Learning mathematical modeling plays an important role in CPS because it can design learning in the classroom by involving students in choosing a theme, students are given the space to determine for themselves what will be studied, what real problems are, thus students are involved in choosing topics, offering them the opportunity to be involved in construction. problems and solutions in the interpretation process students are given the opportunity to provide ideas through pictures, data, tables based on student interests, then the teacher builds interactive discussions both in terms of mathematization, validation until finally the right problem solving is obtained (Galleguillos and Borba 2017). Thus learning will be interesting and can build motivation to learn. Although at this time virtual learning is an alternative, social interaction can also be developed through the internet in a virtual environment, where the outside world can be brought closer to students. In this way, the virtual environment, through the means of information and communication, becomes more relevant to education (Galleguillos and Borba 2017).

This research was conducted on prospective elementary school teachers and obtained research results which said that the CPS ability was still low. So there needs to be training for prospective elementary school teachers because later they need to be involved in teaching and introducing CPS to students at the elementary level. Thus

students in elementary school are familiar with solving complex problems. Thus they become ready to use CPS in their classrooms later, when they become teachers. The required complex problem solving training should consist of three dimensions, namely the cognitive dimension, which includes two sub-dimensions, one related to mathematical concepts and the other related to mathematical modeling; metacognitive dimension, which aims to develop students' critical abilities in validating mathematical models; and affective dimensions, related to the value of mathematical models and modeling and their uses in everyday life. In addition, because everyday life situations are multidisciplinary and mostly include a science dimension, CPS training and mathematical modeling can call for collaboration between mathematics and science subjects. Thus, training is urgently needed to improve the educational competence of prospective elementary school teachers through training and teaching mathematical modeling (Viseu, Martins, and Leite 2020).

The same thing was also suggested by (Vorhölter et al. 2019) based on research related to mathematical modeling in Germany it was said that teacher training on the application of mathematical modeling in solving problems, as well as the willingness of teachers to participate in modeling research projects, would have a positive impact on modeling. mathematics and complex problem solving in their classrooms (Vorhölter et al. 2019). Learning mathematics through modeling will have an impact on students' positive attitudes towards mathematics. The involvement of students in learning mathematics to use mathematics in solving real-world problems even complex makes students gain experience in modeling which is very important for their future. By modeling, learning mathematics can bring out values, namely objectivism, openness and promotion (Riyanto et al. 2019). If teachers help students develop positive affective states and not only teach strategies, but also help students develop skills of interpretation, use of reflection, and use of generative skills, these competencies can aid their development as problem solvers. Higher order thinking skills can develop simultaneously with increasing understanding of complex mathematical problem solving processes such as mathematical modeling (Chamberlin, Payne, and Kettler 2020).

To solve complex problems, students can model mathematics or heuristic algorithms or logical thinking that is systematically and structured (Singgih and Ferdinand 2019). As research by Nursyarifah et al. (2016) who concluded that solving complex problems with mathematical modeling is better than solving complex problems without mathematical modeling. One of the innovations to improve complex problem solving through mathematical modeling is research (Yong, Levy, and Lape 2016) which uses the PBL model and combines it with learning mathematical modeling designed to help students more actively experience mathematical modeling in a more authentic way by involving they are in all parts of the mathematical modeling process, besides that, scaffolding is also carried out carefully in making mathematical modeling tasks so that students feel satisfied because they are more involved in the mathematical modeling process so that it is closer to authentic modeling. The mathematical modeling delivered focuses on sustainability and the environment. For example, students were asked to create profitable, yet sustainable fisheries management strategies (Yong et al. 2016).

One suggestion in improving mathematical modeling is to use a Virtual Learning Environment (VLE) which can support the development of students in their interaction and collaboration in solving complex problems, by elaborating modeling projects through the use of technological resources available in this environment. By developing these projects, students learn to question, contextualize, and investigate problems. In addition, they prepare questions that aim to seek, collect, select, organize, and deal with information that enables them to reflect critically on the role of mathematics in their own context. The results of this study indicate that the development of modeling projects in VLE helps students to interact and collaboratively ask and investigate the themes they choose according to their own interests and realities (Orey and Rosa 2018).

CONCLUSION

Complex problem solving as one of the 21st century competencies, school mathematics goals and mathematical abilities. Learning model Mathematical modeling is an activity that involves the translation of a real world problem or situation into a mathematical model in this case students work with the mathematical model and use it to understand problems and solve real world problems. CPS indicators include (1) collecting

information systematically, (2) diagnosing problems by integrating the most relevant information, (3) finding potential solutions by building an appropriate problem structure model, and (4) determining solutions and implementing them. While the steps of learning Mathematical Modeling consist of the identification stage, the stage of determining the mathematical model, the stage of determining the model solution, and the stage of interpreting the model solution. From the SPSS test results obtained sig value. (2-tailed): 0.000 < 0.005 on the paired sample t test results so that Ha is accepted, meaning that there are differences in CPS before and after learning mathematical modeling. The stages in the learning model of mathematical modeling have many benefits, especially in improving complex problem solving abilities. Mathematical modeling learning models are needed by teachers so that teacher training is needed, teacher involvement in providing scaffolding in the classroom, mathematical modeling learning models as an innovative learning model as a forum to improve CPS. With the learning model, mathematical modeling provides opportunities for students to convey ideas when interpreting real and complex problems in mathematical form. Thus, the learning model of mathematical modeling has an effect on the CPS ability of prospective elementary school teachers.

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