jurnal 3

by Zaka Hk Oki

Submission date: 08-Jun-2023 08:33AM (UTC+0700)
Submission ID: 2111403403
File name: J3.pdf (877.39K)
Word count: 4940
Character count: 29021

Jurnal Pendidikan Matematika
Volume 16, No. 3, September 2022, pp. 289-302
P-ISSN: 1978-0044, E-ISSN: 2549-1040, DOI: https://doi.org/10.22342/jpm.16.3.17228.289-302
Website: https://ejournal.unsri.ac.id/index.php/jpm
Accredited by SINTA 2: http://sinta2.ristekdikti.go.id/journals/detail?id=1811

Mathematical Modeling Learning Design with PISA Framework on Grade X Function

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Abstract

Mathematical Modeling is the cornerstone and central aspect of the PISA framework. However, students still encounter difficulties in dealing with problems related to mathematical modeling. This study aims to produce a learning trajectory of mathematical modeling on functions material using the context of an online taxibike. Mathematical modeling activities on functions material are designed using the mathematical modeling cycle in the PISA framework. The subjects in this study were students of class X Bina Ilmi IT Senior High School Palembang. The research method used is validation studies. The research consisted of three stages, namely the preparation stage, the experimental design stage consisting of two cycles (cycle I: pilot experiment and cycle II: teaching experiment) and the retrospective analysis stage. Data was collected through observation, interviews and written test (students' work on the activity sheet and the results of pre-test and post-test). The results showed that learning activities that have been designed can assist students in solving mathematical modeling problems on functions. It begins with the formulate, employed, interprete/evaluate process. Through these mathematical modeling processes, students have a better understanding of functions and become accustomed to using mathematical modeling processes in solving contextual problems related to function material.

Keywords: Design Research, Function, Mathematics Modelling, PISA Framework, Context of Online Taxibike

Abstrak

Pemodelan Matematika merupakan landasan dan aspek sentral dari *framework* PISA. Namun siswa masih kesulitan dalam menghadapi permasalahan yang berkaitan dengan pemodelan matematika. Penelitian ini bertujuan untuk menghasilkan lintasan belajar pemodelan matematika pada materi fungsi menggunakan konteks ojek online. Aktivitas pemodelan matematika pada materi fungsi didesain dengan menggunakan siklus pemodelan matematika pada *framework* PISA 2022. Subjek dalam penelitian ini adalah peserta didik kelas X SMA IT Bina Ilmi Palembang. Metode penelitian yang digunakan yaitu *design research* tipe *validation studies*. Pelaksanaan penelitian ini terdiri dari tiga tahap, yaitu tahap persiapan, tahap desain percobaan yang terdiri dari dua siklus (siklus I: *pilot experiment* dan siklus II: *teaching experiment*) dan tahap analisis retrospektif. Pengumpulan data dilakukan dengan observasi, wawancara dan tes tertulis (hasil kerja peserta didik pada lembar aktivitas serta hasil *pre-test* dan *post-test*). Hasil penelitian menunjukkan kegiatan pembelajaran yang telah didesain dapat membantu peserta didik dalam menyelesaikan permasalahan pemodelan matematika pada materi fungsi. Diawali dengan proses *formulate*, *employed*, *interprete/evaluate*. Melalui proses-proses pemodelan matematika tersebut membuat peserta didik memiliki pemahaman yang lebih kuat tentang fungsi dan menjadi terbiasa menggunakan proses pemodelan matematika dalam menyelesaikan permasalahan kontekstual berkaitan dengan materi fungsi.

Kata Kunci: *Design Research,* Fungsi, Pemodelan Matematika, *Framework PISA,* Konteks Ojek Online

How to Cite: Saputri, N. W., Zulkardi, & Darmawijoyo. (2022). Mathematical modeling learning design with PISA framework on grade X function. *Jurnal Pendidikan Matematika, 16*(3), xx-xx.

Received March 16, 2022; Revised May 28, 2022; Accepted August 22, 2022

INTRODUCTION

Function is one of important topics in mathematics that deals with the study of quantities, patterns, relationships, and formed structures (NCTM, 2021; Warsitasari, 2015). An understanding of functions in mathematics is crucial so that students are able to identify and interpret the relationship between two variables and to support students' future success in learning mathematics (i.e. advanced mathematics, calculus, or algebra) (Yuniati, et al, 2019; Burns-Childers & Vidakovic, 2017; Bardini et al, 2014). Understanding the function material means to use a dependent relationship, namely by emphasizing the value of one thing depending on or determined by another value (Kalchman & Koedinger, 2005; Blanton, et.al, 2015). Students understand that x can vary in the value it represents and the value of y or $f(x)$ depending on the value of x (Doorman & Drijvers; 2011).

The difficulties experienced by students in algebraic functions are applying arithmetic operations, understanding the meaning of variables and algebraic expressions, and making mathematical models (Jupri & Drijvers, 2016). Fuson and Bransfod (2015) also found that students had difficulty when they had to form functions from various different representations. According to Fuson and Bransfod, these difficulties reflect an incomplete conceptual framework for functions, so that they do not provide a solid basis for flexible movement in representing functions.

Developing a function of real world problems, is related to mathematical modeling. According to the NCTM (2021) the standard of algebraic mathematics content on function material expect that students can represent and analyze mathematical situations and structures using algebraic symbols, and use mathematical models to represent and understand the quantitative relationship of a problem. Mathematical modeling ability is an ability that must be possessed by students. Mathematical modeling is the process of using mathematics to represent, analyze, make predictions, or provide insights into real-world phenomena (Bliss & Libertini, 2016). By having mathematical modeling skills, students can relate real-world problems in the form of mathematical symbols (Saputri & Zulkardi, 2020). Mathematical modeling ability is also an ability that is a key feature in the PISA test (OECD, 2018). In the 2022 PISA Framework, the stages of mathematical modeling are divided into three processes, which are formulating, using mathematical concepts, facts, and procedures, as well as interpreting and evaluating mathematical results. One of the main understandings underlying school mathematics that is at the core of mathematical literacy in PISA is recognizing functional relationships between quantities, and using mathematical modeling as a real-world lens (OECD, 2018).

The process of mathematical modeling in the PISA framework begins with a problem in a context. According to Sadan (2020), the process that is the outline in mathematical modeling is a key component of solving real-world problems, where the starting point is the problem in its context. The problem will be solved using mathematics and then projected back into a real-world context problem (Niss, 2015; Doerr, Arleback, & Misfeldt, 2017). A certain context or situation can generate various

mathematical understandings and each situation also has the potential to deeply explore mathematical ideas on which mathematical concepts are built (Zbiek, Blume & Heid, 2018). The context used in learning mathematics can be made through linking mathematics with students' daily lives and technological developments that students can understand (Prahmana, Zulkardi, & Hartono, 2012; Widiati, 2015; Putri, 2015). Meanwhile, according to Wijaya, Van den Heuvel-Panhuizen, Doorman, and Veldhuis (2018), providing context-based tasks that require mathematical modeling gives students opportunities students to learn and improve problem solving skills. In addition to improving students' mathematical thinking skills, the use of contexts or situations that are close to students can provide students' natural motivation to learn mathematics to help students get to know mathematics through situations (Lee, et.al, 2020). In relation to the function material, according to Doorman and Drijvers (2011), providing situations that are close to students can generate the need to develop a series of calculation patterns and provide opportunities for teachers to introduce aspects of dependent relation.

One of the contexts that is close to students and in accordance with the theory of learning and teaching functions is an online taxibike. During the current COVID-19 pandemic, there has been an increase in the number of users of this online taxibike application. Several services in the online taxibike feature have increased such as goods and food delivery services which have increased by 90% during the COVID-19 pandemic (Liputan6.com, 2020). This shows that online taxibike is an that students are familiar with the application. In the context of online taxibike, there is a linear relationship between the distance traveled and the total fare that must be paid by consumers. Therefore, the context of online taxibike can be used to explain the dependent relationship in the general form of a linear function formed from the total cost function of the distance traveled.

There are many studies related to PISA. Some of them are the development of PISA questions that are used in learning (Zulkardi & Kohar, 2018) and describe certain abilities such as higher order thinking (Meryansumayeka, et.al, 2020), creativity (Novita & Putra, 2016) and the development of PISA type questions with various contexts, including the context of the Asean Games (Efriani, Putri & Hapizah, 2019; Jannah, Putri & Zulkardi, 2019; Putri, & Zulkardi, 2020), COVID-19 (Saputri, et.al, 2020; Nusantara, Zulkardi, & Putri , 2021), and local context (Charmila, Zulkardi, & Darmawijoyo, 2016; Dasaprawira, Zulkardi, & Susanti, 2019; Turidho, et.al, 2021). However, no study has designed learning related to the mathematical modeling cycle used the PISA 2022 framework.

To achieve this, this study aims to produce a learning trajectory of mathematical modeling using the PISA framework on function material in the context of online taxibike. The mathematical modeling process used the PISA 2022 framework.

METHODS

The method used in this research is design research type validation studies. This study aims to produce a learning trajectory of mathematical modeling on function material using the context of an online taxibike. The subjects in this study were students of class X SMA IT Bina Ilmi Palembang in the 2021/2022 academic year.

This research consists of three stages. The first stage is preparing the Experiment, namely the preparation stage consisting of literature review and designing Hypothetical Learning Trajectory (HLT). HLT contains learning activities in the form of alleged strategies and thoughts of students that develop during the learning process of mathematical modeling. The second stage is experimental design. At this stage it consists of two cycles, the first cycle is called the pilot experiment, which is testing the HLT that has been designed on students in small groups consisting of 8 students who have different abilities, which are high, medium, and low. In this stage is used to collect data in adjusting and revising the HLT which will later be used during the teaching experiment which is the second cycle of the experimental design stage.

The HLT that has been designed and repaired after conducting the pilot experiment will be tested in the actual class that is the subject of the research. Then the third stage is retrospective analysis. The data obtained from the teaching experiment stage will be analyzed in the retrospective analysis stage by comparing the HLT that has been developed with the actual learning. Data collection techniques in this study were observations, interviews and analysis of written works (students' work on the activity sheet and the results of pre-test and post-test).

RESULTS AND DISCUSSION

This study resulted in a learning trajectory of mathematical modeling using the PISA framework on function material in the context of online taxibike. Before obtaining the learning trajectory, the researcher first developed a Hypothetical Learning Trajectory (HLT). The HLT developed in this study uses the context of online taxibike and is based on cycles of mathematical modeling. The context of online taxibike was chosen because online taxibike is a familiar means of transportation for students; most students have used online taxibike services. The context of problems that are familiar to students will make students more connected to mathematical material (Andreescu, Cordeiro, & Andreescu, 2020). Lee, et.al (2020) also revealed that with the right context, students can know that mathematics is a human activity that is around them, can learn mathematical principles and concepts naturally through their own activities, and can increase their interest and gain knowledge positive attitude towards mathematics. Figure 1 below is the HLT that has been developed in research on function material using stages of mathematical modeling in the context of online taxibike. The HLT was developed into 4 activities which were used in 3 meetings.

In the first meeting, the activities given are activity 1 and activity 2. In activity 1, the context used is Go-box and aims for students to determine and identify the relationship between the domain and range of a function and form a formula in linear function notation. From the results of activity 1, it was found that students were able to identify the relationship between the domain and range of a function and were able to make mathematical models in the form of linear functions. This can be seen from Figure 1. Students already understand the rules applied to the go-box. They can calculate the cost of the go-box with certain distances. Then, students are also able to identify variables and create mathematical models in the form of linear functions.

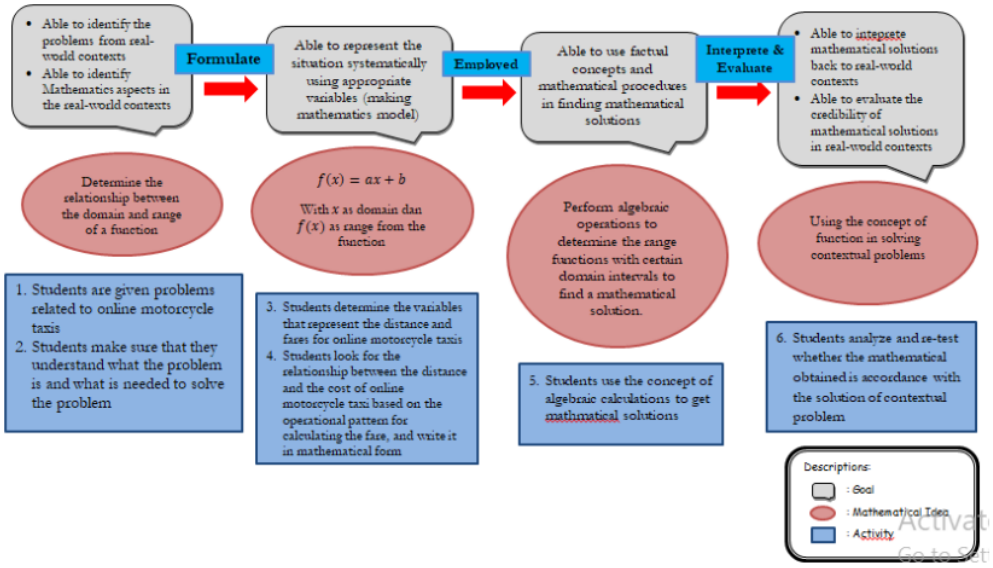


Figure 1. HLT on functional materials using the mathematical modeling stage in the PISA framework

In activity 2, the problem given uses the context of the Go-Ride Driver and aims to make students able to determine and identify the relationship between the domain and the range of a function and can form formulas in the notation of the piecewise function through real problems. From the results of activity 2, it was found that students were able to identify the relationship between the domain and range of a function and were able to create mathematical models in the form of a piecewise function. The following is a snippet of student answers in activity 1. Figure 1 above shows that students are able to formulate situations mathematically (making mathematical models). Before the students make mathematical models, the teacher ensures that they understand the problem by asking questions on the activity sheet that indicates to the ability of students to understand the problems and situations that exist in the problem. Understanding the mathematical context and

situation that exists in the problem is something that really needs to be considered to identify relevant variables and appropriate assumptions that may be formed from real models (Niss & Blum, 2020). This part of the pre-mathematization process is needed to prepare for the next mathematization situation (Stillman & Brown, 2014; Niss, 2017; Czocher, 2018).

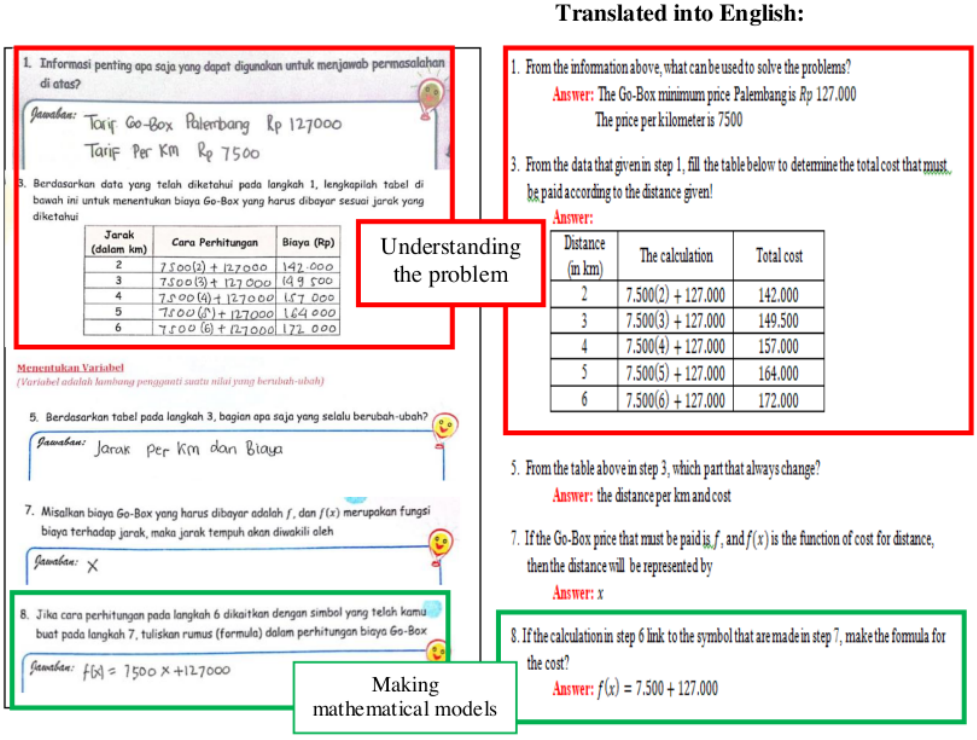


Figure 2. Snippets of student answers in activity 1 about calculating go-box fees

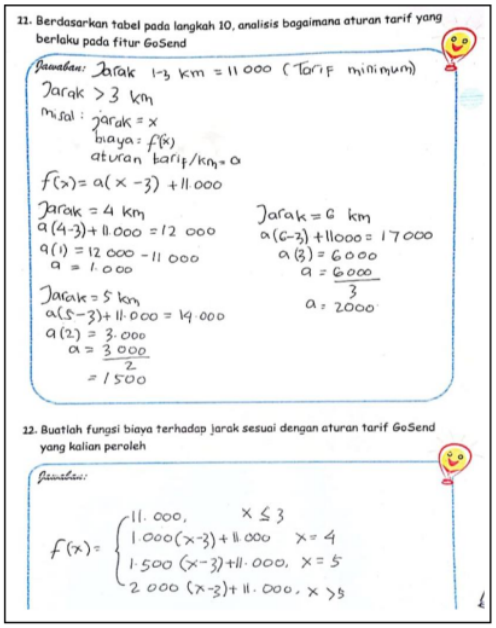
In the second meeting, the activity given was activity 3 (see Figure 2). This activity 3 enables students to apply their knowledge of functions in everyday life. In activity 3, students use facts, concepts, mathematical procedures to solve problems (employed) and interpret, apply and evaluate the mathematical results obtained (interpret/evaluate). In this case, students compare the costs between two online taxibikes and students can provide conclusions based on the mathematical model that has been formed and the mathematical solutions found. Students are also able to evaluate mathematical models and mathematical solutions to the conclusions that have been obtained. From the results of activity 3, it was found that students were able to use their knowledge of functions to solve problems in real contexts. In this activity, students are able to reflect on the mathematical solutions obtained back into the context of the real-world problems that started the process (OECD, 2019).

In the third meeting, the activity given was activity 4. The problem presented in activity 4 was about ordering go-send. Activity 4 begins with students checking the cost and distance traveled from

several intended locations (Figure 3).

Figure 3. Students using smartphones to open online ojek applications on piecewise function materials

Then, students record the distance and costs written in the application on the activity sheet provided. Activity 4 is done so that students can create mathematical models in the form of functions of contextual problems and use these models to solve problems from real contexts.



Translated into English:

11. From the table in step 10, analize the alternative ways in Gosend features.

Answer: Distance 1 – 3*km* = 11.000 (Minimum price)
Distance > 3
If: *Distance* = x
Cost = $f(x)$
Cost rule = a
$f(x) = a(x-3) + 11.000$

Distance = 4*km*
$a(4-3) + 11.000 = 12.000$
$a(1) = 12.000 - 11.000$
$a = 1.000$

Distance 5*km*
$a(5-3) + 11.000 = 14.000$
$a(2) = 14.000 - 11.000$
$a = \frac{3.000}{2}$
$= 1.500$

Distance 6*km*
$a(6-3) + 11.000 = 17.000$
$a(3) = 17.000 - 11.000$
$a = \frac{6.000}{3}$
$a = 2.000$

12. Make a cost function against distance that accoding to the Go-send rule that you got.

Answer:

$$f(x) = \begin{cases} 11000 & x \le 3 \\ 1000(x-3) + 11000 & x = 4 \\ 1500(x-4) + 11000 & x = 5 \\ 2000(x-5) + 11000 & x > 5 \end{cases}$$

Figure 4. Students' answers determine go-send rates rules and write in the form of piecewise functions

From the results of activity 4 (Figure 4), it can be seen that students are able to use their knowledge of algebra to determine the go-send tariff rules which can be seen from students using the

function concept they have learned and by using algebraic operations, students can determine the applicable tariff rules and developed a mathematical model in the form of a piecewise function. The function of the branch that has been formed is used by students to answer the problem, namely estimating the cost of go-send with a certain distance without using an application.

After learning, students are given post-test questions which consist of 2 questions and the questions are done individually. The post-test is given to see the extent to which the students understand the function material and apply their knowledge in solving problems in everyday life. The following are students' answers to the post-test questions.

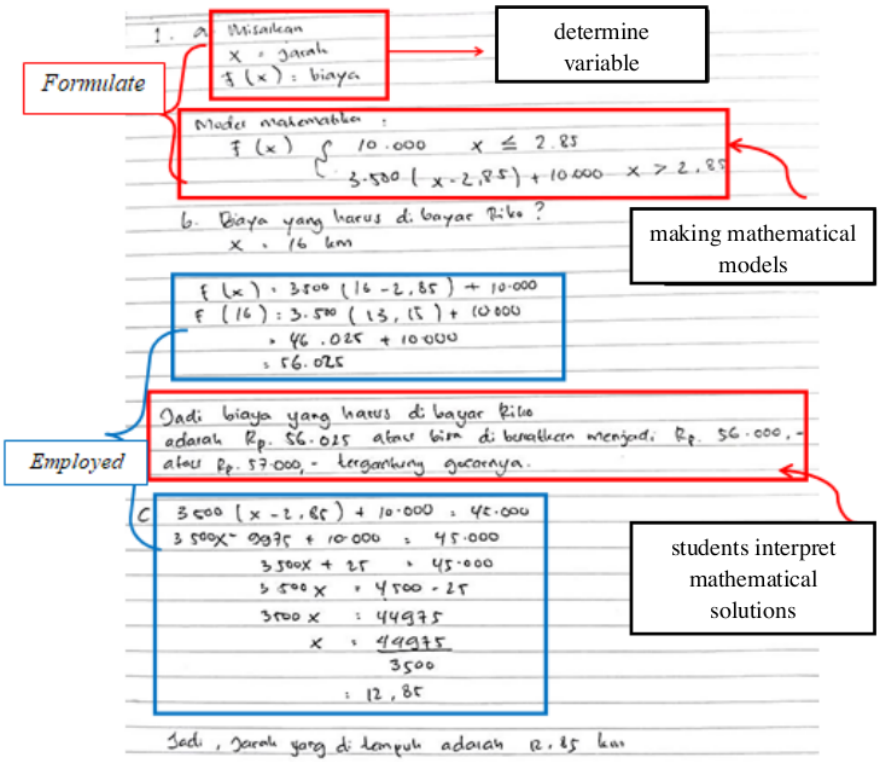


Figure 5. Students' answers on post-test questions on function materials using the mathematical modeling stage

Based on Figure 5, it can be seen that students are able to formulate, that is by making mathematical models in the form of functions of the contextual problems presented. Students are able to identify the mathematical aspects of a problem in a real-world context and represent situations systematically by using variables to create mathematical models. According to Frejd and Bergsten (2016) and Kaiser (2017), mathematical modeling is idealized as a process that transforms questions from the real world into mathematically well-structured problems.

Then, the students are also been able to complete work, which is to do and use the model to solve problems, and students are able to interpret, which is to interpret mathematical solutions that have been obtained back into the real-world context. According to Doer, Arleback, and Misfeldt (2017) and Sadan (2020) mathematical modeling is a key component of real-world problem solving, i.e. problems will be solved using mathematics and the results will be projected back into the real-world context.

This learning is designed to produce students' mathematical modeling learning trajectories in the function material in class X. The description of the learning trajectories is carried out, starting from the development of students' abilities to formulate, employ, and interpret/evaluate which is a mathematical modeling process described in the PISA framework (OECD, 2018; Sadan, 2020). Activities developed using the context of online taxibike with mathematical modeling steps in the PISA 2022 framework are a bridge from informal knowledge to formal knowledge, then back to informal knowledge.

This study found that before getting the solution to the given problem, the students first formulated the situation mathematically and represented the situation mathematically (making mathematical models). According to Sadan (2020), the activities should be given after identifying relevant variables and making a mathematical model. In this case, the mathematical model formed is a linear function and piecewise fuction. The mathematical model is formed when the students have found a pattern of relationships between two quantities. Dependent relationship is the way to understanding the function material, namely the value of something that is determined or depends on another value (Kalchman & Koedinger, 2005; Wang, Barmby & Bolden, 2015; Blanton, 2015). The researchers use tables so that students can see the pattern of relationships that occur. Organizing data in a table and paying attention to the types of relationships depicted in the table can help to generalize the relationship between two quantities and provide an illustration to express this relationship in words and variable notation (Blanton, 2015). Then, the mathematical model in the form of a function can be made as an algebraic generalization of the input-output calculation pattern from a real situation (Doorman & Drijver, 2011).

In the process, learning begins with orienting students to the problem. The problems given are designed using a familiar context for students, namely online taxibike. During the learning process that occurs, students look enthusiastic. Students are also able to understand the problem very well. This is because the context of the problem is designed using a context that is close and familiar to them. Problems that are familiar to students will make students more connected to mathematical material (Andreescu, Cordeiro, & Andreescu, 2020). Lee, et.al (2020) also revealed that with the right context, students can know that mathematics is a human activity around them, can learn mathematical principles and concepts naturally through their own activities, and can increase their interest and gain knowledge positive attitude towards mathematics.

CONCLUSION

This study produced in a learning trajectory of mathematical modeling on function material in the context of online taxibike. Learning is designed by bringing up the mathematical modeling process in the PISA framework, in which students identify problems in the real-world context, represent situations mathematically by formulating the relationship between the domain and range of a function, and create mathematical models in the form of linear functions and piecewise functions. In the process, students are able to use their abilities in performing arithmetic and algebraic operations to find mathematical solutions to problems that have been made in the form of functions. Then, students use interpreting abilities to interpret mathematical solutions back to the real-world context and evaluate their abilities to evaluate mathematical models with the reasonableness of solutions obtained in the context of online taxibike.

ACKNOWLEDGMENTS

Thank you to Mrs. Rahmah Wulandari, S.Pd as a model teacher and to the tenth grade students of SMA IT Bina Ilmi Palembang for being willing to be the subjects of this research.

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