Learning mathematics through mathematical modeling approach using jembatan musi 2 context

Bambang Riyanto1, Zulkardi1, Ratu Ilma Indra Putri1, and Darmawijoyo1
1Universitas Sriwijaya, Jalan Sriwijaya Negara, Bukit Besar, Palembang, Indonesia
*Email: bambangriyantomath@gmail.com

Abstract. Mathematics becomes more meaningful for students with modeling, and students are interested in this approach. The purpose of this study is how is the modeling of high school mathematics using the context of Jembatan Musi 2 taught in high schools? This study used design research. Based on pilot teaching, learning experiments, and retrospective analysis learning devices and students worksheet are obtained for teachers teaching mathematical modeling, using the context of Jembatan Musi 2.

1. Introduction
Based on one of the Dikdasmen General Policies, namely 2019 Basic and Secondary Education Development Goals stated that the emphasis on improving the quality of learning at all levels and pathways of education, both publicly available to facilitate improvement [1]. This is a challenge for teachers in schools who must contribute to the implementation of this successful policy. The author, in this case, provides a solution for teachers in schools to learn mathematical modeling learning theories, such as how to design mathematical modeling tasks, how to design mathematics modeling learning in schools as an effort to improve the quality of learning in schools. There are several changes emphasized in the 2013 curriculum, namely, competence, content, methods, and conversations [1]. Mathematical content in the 2013 Curriculum focuses on material that supports the development of punishment, problem-solving skills, argumentation, modeling, and communication skills in mathematics. This shows that mathematical modeling is also handled in the 2013 curriculum. To achieve this, the teacher should implement the application of mathematical modeling learning in the 2013 curriculum.

Based on the characteristics of the 2013 curriculum, we can see that the characteristics of the 2013 curriculum are similar to mathematical modeling learning. Furthermore, according to [1] that PMRI is a vehicle for implementing the 2013 curriculum. Furthermore, [2] states that PMRI is not much different from Mathematical Modeling. Thus, learning mathematical modeling is very suitable for learning in the 2013 curriculum. Statement [3], mathematics is feared for the following reasons: teacher terror, learned helplessness, neglect or parents who trigger pressure, defamation of society, instant gratification, lack of motivation, and test failures. This concern indicates the need for mathematical modeling learning.

According to [4] that the main problem with mathematics education is the relationship of physical intuition (empirical source of mathematical ideas) to be seriously degraded, if not broken together. Modeling activities create opportunities for young learners to understand mathematics because it is useful and applied, rather than abstract and isolated [5, 6]. According to [7], the biggest reason why students perform poorly in mathematics is that they are still having trouble finding mathematical relevance in their lives. Teachers should find ways to make their class like mathematics by trying to
bring out new teaching techniques and methods that will prepare students interested and involved [8].

So, learning mathematics with a modeling approach is very crucial to implement.

Jembatan Musi 2 was the object that was familiar with the student. Mathematical learning is still not using mathematical modeling. So, this study used jembatan musi 2 contexts in mathematical modeling learning. This is also suitable with the research of [9] that student was interesting to mathematical learning using mathematical modeling tasks. Based on this background, the purpose of this study was to produce learning devices and student worksheets used to teach mathematical modeling using the context of the Jembatan Musi 2.

2. Method

This research use method of Design Research. With this method will be produced products and scientific processes or guidelines in completing the product [10].

In this research, the product will be developed in this case local instructional theory (LIT) for students and teachers in modeling learning. The theory used is the PMRI and PISA framework. The process starts with the researcher doing the experimental thought (thought experiment) based on the results of literature review and experience, then continued use of the product in the process of instructional experiments (instructional experiment). Figure 1 below represents a cyclical process of research design started by Gravemeijer and Cobb [10].

![Figure 1. The reflexive relationship between theory and experiment](image)

The research will be conducted by designing and evaluating through three stages, that is preliminary design, teaching experiment, and retrospective analysis [11]. Preliminary Design or Preparation for Research/Design Introduction is a stage consisting of a literature review and Designing Learning Materials or Trajectories [12]. In the stage of literature review done by studying a curriculum and literature study on PMRI and Modeling using Jembatan Musi 2 in Mathematics was conducted. In the stage of designing learning materials or trajectories done by Hypothetical Learning Trajectory (HLT) Design consists of three components: firstly, learning objectives; secondly, learning activities, in this component researcher desing mathematical modeling tasks using jembatan musi 2, and lastly, the allegations or hypotheses of the learning process to predict how students' thoughts and understanding are. This assumption is dynamic so that it can be adapted to the reactions of students in learning and revised during teaching experiment. At the teaching experiment stage, there is two-step, that is a pilot experiment and teaching experiment. The pilot experiment was conducted to pilot HLTs that had been designed for students in small groups of 3 students to collect data in adjusting and revising the initial HLT for use in the later experimental stage. In the teaching Experiment, the HLTs that have been piloted at the pilot experiment stage and have been repaired are re-examined in the class, which is the subject of the study. After the test is Retrospective Analysis, the data obtained from the learning activities in the class were then analyzed, and the results were used to plan the activities or to develop the design on the next learning activity. The purpose of Retrospective Analysis to develop LIT or Local Instructional
Theory. LIT here is a track that has tested both the product and the process.

Subjects in this study were grade XI Science 1, XI Science 2, and XI Science 3 of Senior High School Number 1 Palembang. In this study, the instrument used is student worksheet Mathematical Modeling using jembatan musi 2 contexts. Data are collected in the following manner: (1) Observation, (2) questionnaire, (3) documentation, and (4) field notes.

3. Result and Discussion

3.1. Results

The research was conducted at SMA Negeri 1 Palembang. In this study, modeling learning used the context of the Jembatan Musi 2. Pilot teaching was held on Tuesday, March 5th, 2019 students of class XI IPA 1 in SMA Negeri 1 Palembang with a subject of 15 students. From student opinion, the student says that mathematics in everyday life is very much needed in our curriculum. This opinion is given by students when they finish pilot teaching. Student comments are in figure 2 as follows.

![Figure 2. Student’s Comment](image2)

Judging from the solution of students in one-to-one and small groups, students have not provided more specific mathematical models, have not been able to validate. Here is figure 3, the student’s solution.

![Figure 3. Student’s Solution](image3)

Then the researcher conducted experimental teaching. Experiment teaching was conducted on Thursday, March 14, 2019, again conducted teaching experiment in class XI IPA 3. Next figure 4, students were discussing on doing mathematics.
In this teaching experiment, students have been able to bring up mathematical models of quadratic functions. Here is figure 5 of the student solution.

![Figure 5. Student’s solution for the arch of Jembatan Musi 2](image)

Viewed from learning activities with mathematical modeling, students are very enthusiastic about learning mathematics, which can be seen videos and observations. Aside from that, For the context of Jembatan Musi 2, students can emerge two models, namely assuming the arch of the Jembatan Musi 2 is a quadratic function and a trigonometric function. Here is a solution to the mathematical model that they found. Figure 6 below is a mathematical model from the student’s solution.

![Figure 6: Mathematical model of Jembatan Musi 2](image)
After doing experimental teaching, researchers conducted a retrospective analysis. In this step, the researcher sees that mathematical modeling tasks using Jembatan Musi 1 contexts was interesting and resulting in two mathematical models. This also can be seen from the comments of the model teacher, the observer, and the students themselves are interesting, challenging, and meaningful for students and make students motivated to learn. So, we get LIT in form learning device and student worksheet to learn mathematics using mathematical modeling tasks using Jembatan Musi 2 contexts. This also can be seen from the comments of the model teacher, the observer and the students themselves are exciting, challenging, and meaningful for students and make students motivated to learn.

3.2. Discussion

Research from [13] has examined modeling as a professional task in the workplace, which shows that the influence of scientific knowledge on school mathematics is weak. Several theoretical constructs have been developed, which provide an approach on how to design and develop modeling activities for teaching mathematics, but still a challenge [14]. In the USA, there is a great effort to introduce mathematical modeling in schools [15]. According to [14] that the design of mathematical didactic activities consists of design assignments, learning (lesson), teaching sequences, textbooks, curriculum, assessment, and ICT-based material or programs for teacher education and can be carried out by teachers, educators, authors of books, curriculum developers and assessments, ICT designers, and researchers.

Without design, no education is possible [16]. According to [17] that mathematics education is not only about the process of teaching mathematics, but also emphasizes ideas and knowledge about how to learn mathematics, about how mathematics can be best taught and what mathematical content should be taught and why. Mathematics as a human activity, rejecting mathematics education as teaching mathematics had already been made to students, and stimulus to mathematical processes [18]. According to [19] that students need an understanding of the connection between mathematical concepts and their applications in their world in contexts that are directly related to relevant topics and are of interest to them. This shows that students need mathematical modeling learning in everyday mathematics learning. Mathematical modeling combines 21st-century learning ideals and skills [20]. Too often, the power and beauty of mathematical ideas are learned (taught) in the manner of procedures, thus depriving students of the experiences they make and refining their ideas [21].

In modeling problems, students are offered plentiful learning opportunities [22]. The use of modeling activities encourages students to develop important mathematical ideas and processes that students normally would not meet in the traditional school curriculum [22]. Mathematical modeling has been considered to be an effective medium to prepare students to deal with unfamiliar situations by thinking flexibly and creatively and to solve real-world problems [23, 24].

De Lange emphasizes in his reflection that designers need to find context by finding real worlds outside mathematics and experience potential contexts by going to real classes [25]. Creative designers such as De Lange, people who can assure other limitations of many textbooks and who can translate the idea of general education into original and interesting sources for students, are important for realizing meaningful and relevant mathematics education [17]. Designing tasks that make certain mathematical activities for students a challenge, not only in the Netherlands but also in the mathematics education community throughout the world [17]. According to [15] that if we succeed in teaching modeling in high school, then the problem is to keep him alive and use it at the college level. If we fail to teach modeling at the secondary school level, then other people must teach it at the high school level. This statement shows the importance of mathematical modeling at both the secondary and tertiary level. According to [26] stated that despite increasing interest in modeling, we see that many mathematics teachers still do not use mathematical modeling as teaching practice in the classroom. This shows the need to guide mathematics teachers in schools to implement mathematical modeling learning in schools.

According to [25] states, high school students can successfully participate in mathematical modeling activities and their abilities in mathematical modeling increase over time. When students do not use all
the mathematical possibilities designed into the activity, the teacher can use MEA and mathematical modeling as formative assessments to build students' understanding and further develop ideas that are in the mind of the teacher to pursue [27]. One of the benefits of mathematical modeling is that students can develop 21st-century competencies, including communication and teamwork skills, which will help them in their lives and any career [27]. Mathematical modeling is often done in groups that can develop students' abilities to describe, explain, clarify, and argumentation [28]. According to the findings [29] that in mathematical modeling, students develop themselves doing mathematics and produce the forms of knowledge they build together. According to [15] that the fact that primary and secondary students throughout the world study a subject called "mathematics", with content and methods that are relatively similar intrinsically related to certain assumptions about relevancy if not the necessity of this subject for every citizen in modern society and the formulation of these assumptions changes over time and of course it is the object of constant debate, but the general invariance of opposition seems to be the usefulness of what is taught in actual or future life of students, or at least the role of mathematics outside school.

Understanding multiple representations of mathematical problems can be difficult for many students [30]. This shows that the need for a solution in mathematics learning that involves real-world problems, namely mathematical modeling. According to [26] that Modeling education as a method of teaching mathematics aims to provide students with a better understanding of mathematical concepts, train them to read, interpret, formulate and solve specific problems, and to arouse their critical and creative senses. To apply it in teaching, the teacher chooses a theme/subject from all fields of knowledge that can attract students (according to the content of the program) and mathematical design models, adjust them to teach. Mathematical modeling is challenging for students [29]. This challenge consists of the difficulty of working with each step in the modeling cycle, and also the challenges of carrying out the overall modeling cycle. This challenge suggests that it is important to focus on how to help students do mathematical modeling [31].

Studies have shown that when students get the opportunity to be involved in authentic modeling assignments, they are more motivated in learning, and they enhance student achievement [32, 33]. Through modeling, mathematics can be assessed by the community, and students confident in the appreciation and learning of mathematics for careers becomes more meaningful and relevant [20]. According to [34] states that Application and modeling are essential, and application learning and modeling are demanding. Research [26] that in the development of the method, they call Mathematics Education (modeling), which uses the main principles of modeling in the teaching process and Mathematics learning at each school level.

Several studies have shown that mathematical modeling learning can help improve problem-solving skills and reduce the level of student mathematics anxiety, where these two are common problems in mathematics [22, 35, 36]. According to the results of the study [37] that the Mathematical Modeling Method plays a role in students' mathematical abilities, because students can reconstruct concepts that have been learned so they can build their reasoning and also Mathematical Modeling methods can create mathematical learning environments in real-world problems and also Mathematical Modeling also has a large role in student attitudes because they participate in social development so that they have a better understanding of the real world. Based on the findings from [38] that learning by modeling and understanding mathematics the average activity is increased during the implementation of the mathematical and educational modeling processes provided during this process is effective.

The results of the study [9] concluded that (a) Both the use of mathematical modeling and guided practice in the classroom significantly improve the problem solving performance of middle school 9th grade students, (b) The use of mathematical modeling significantly decreases the level of mathematics anxiety of 9th grade middle school students especially in terms of social responsibility anxiety and math test anxiety. However, it does not affect students' numerical anxiety, (c) Mathematical modeling is more effective than the use of guided practice in teaching topic-solving problems in mathematics, and (d) The use of mathematical modeling, compared to the use of guided practice, in teaching problem solving, is more effective in reducing mathematics anxiety in grade 9 middle school students, specifically in terms
of numerical anxiety, math test anxiety and its combination. However, in terms of social responsibility anxiety, both strategies are equally effective.

One field of mathematics that has the potential to obtain the use of student algebraic reasoning is mathematical modeling [31]. The three main benefits of mathematical modeling described in research [31] are that it mimics the way mathematics is done in the real world, allowing students to engage in contexts that interest them and promote justice in mathematics education.

4. Conclusion
This research produces a local instructional theory (LIT) for mathematical modeling learning using “Jembatan Musi 2” contexts in form learning device and students worksheet.

5. References
[1] Zulkardi and Putri R I I 2019 New School Mathematics Curricula, PISA and PMRI in Indonesia. In Vistro Yu C and Toh T eds School Mathematics Curricula. Mathematics Education – An Asian Perspective. Springer, Singapore.
[2] Zulkardi 2017 Modelering dalam Pendidikan Matematika Realistik Indonesia. In Seminar Nasional Matematika dan Pendidikan Matematika: Fenomena Non-Linier dan Pembelajaran Pemodelan Matematika
[3] Lee – Chua Q N 2012 Even scientists suffer from math anxiety. Philippine Daily Inquirer. Retrieved from http://newsinfo.inquirer.net/258226/even-scientists-suffer-from-math-anxiety
[4] Hestenes D 2013 Modeling Theory for Math and Science Education. In Richard L Peter L G Christopher R H Andrew H Modeling Students’ Mathematical Modeling Competencies ICTMA 13
[5] Blum W Galbraith P Henn H W and Niss M 2007 Modelling and Application in Mathematics Education. In W Blum P L Galbraith H W Henn and M Niss Eds Modelling and Application in Mathematics Education. The 14th ICMI Study
[6] Greer B Verschaffel L and Mukhopadhyay S 2007 Modeling for life: Mathematics and Children’s experience. In W Blum P L Galbraith H W Henn and M Niss Eds Modelling and application in mathematics education: The 14th ICMI Study
[7] Rysdon A 2010 Math Students Can Relate To. Retrieved from https://www.chatham.edu/pti/curriculum/units/2010/2/Rysdon.pdf
[8] Santos M L K P Diaz R V and Belecsa R R 2015 Mathematical modeling: effects on problem solving performance and math anxiety of students. International Letters of Social and Humanistic Sciences 65 103
[9] B Riyanto et al 2018 J. Phys.: Conf. Ser. 1097 012102
[10] Akker J Bannan B Kelly A E Nieveen N and Plomp T 2006 Educational Design Research (Enschede: SLO)
[11] Plomp T 2013 Educational design research: An introduction. Educational design research 11-50
[12] Prahmana R C I 2017 Design research: Teori dan implementasinya: Suatu pengantar (Jakarta: Raja Grafindo Persada)
[13] Frejd P and Bergsten C 2016 Mathematical modelling as a professional task. Educational Studies in Mathematics 91 11
[14] Jessen B E 2016 Study and Research Paths at Upper Secondary Mathematics Education Doctoral Dissertation (Copenhagen: University of Copenhagen)
[15] Pollak H 2013 A View of Mathematical Modeling in Mathematics Education Proceedings Conference on Mathematical Modeling Teachers College Columbia University
[16] Blum W Artigue M Mariotti M A Straßer R and Heuvel-Panhuizen M V 2019 European Didactic Traditions in Mathematics: Introduction and Overview In European Traditions in Didactics of Mathematics (Switzerland: Springer)
[17] Heuvel-Panhuizen M V D 2019 Didactics of Mathematics in the Netherlands European Traditions in Didactics of Mathematics (Utrecht: Springer)

[18] Freudenthal H et al 2002 Revisiting Mathematics Education (Dordrecht: Kluwer Academic Publishers)

[19] Stillman G Brown J and Galbraith P 2010 Researching Application and Mathematical Modelling in Mathematics Learning and Teaching Mathematics Education Research Journal 22 1 – 6.

[20] Asempana R S 2015 Mathematical Modeling: Essential for Elementary and Middle School Students Journal of Mathematics Education 8 16

[21] Larson C et al 2013 Modeling Perspectives in Math Education Research In Richard Lesh Peter L Galbraith Christopher R Haines Andrew Hurford Modeling Students’ Mathematical Modeling Competencies ICTMA 13 (London: Springer)

[22] Mousoulides N G Pitulis M and Christou C 2006 Improving Mathematical Knowledge Through Modeling in Elementary Schools Proceedings 30th Conference of the International Group for the Psychology of Mathematics Education 4 201

[23] Lesh R and Doerr H M 2003 Foundations of a models and modeling perspective in mathematics teaching and learning In R A Lesh and H M Doerr (Eds) Beyond constructivism: Models and modeling perspectives on mathematics problem solving learning and teaching pp 3-34 (Mahwah NJ: Lawrence Erlbaum Associates)

[24] English L D 2006 Mathematical modeling in the primary school: Children's construction of a consumer guide Educational Studies in Mathematics 63 303

[25] De Lange J 2015 There is probably no need for this presentation In A Watson and M Ohtani (Eds) Task design in mathematics education—ICMI Study 22 pp 287–308 (Cham: Springer)

[26] Biembengut M S and Hein N 2013 Mathematical Modeling: Implications for Teaching In Richard Lesh Peter L Galbraith Christopher R Haines-Andrew Hurford Modeling Students’ Mathematical Modeling Competencies (London: Springer)

[27] Stohlmann M S 2017 Mathematical Modeling with Middle School Students: The Robot Art Model-Eliciting Activity European Journal of STEM Education 2

[28] English L and Watters J 2005 Mathematical modelling in the early years Mathematics Education Research Journal 16 58

[29] Francisco J M and Maher C A 2005 Conditions for promoting reasoning in problem solving: Insights from a longitudinal study Journal of Mathematical Behavior 24 361

[30] Overmyer G R 2014 The Flipped Classroom Model for College Algebra: Effects on Student Achievement Dissertation (Colorado: Colorado State University)

[31] Deal J 2015 Students' Mathematical Modeling in Algebra Thesis (Urbana: Univerity of Illinois)

[32] Boaler J 2001 Mathematical modelling and new theories of learning Teaching Mathematics and Its Applications 20 121

[33] Pollak H O 2003 A history of the teaching of modelling In G Stanic and J Kilpatrick (Eds) A history of school mathematics 9 647 (Reston VA: NCTM)

[34] Blum W 2015 Quality Teaching of Mathematical Modelling: What Do We Know What Can We Do? The Proceedings of the 12th International Congress on Mathematical Education

[35] Parker M and Bedford D 2001 Problem Solving and Mathematical Modelling: Applicable Mathematics Retrieved from http://www.transmaths.org/mmmp/ FinalReportKeele pdf

[36] Das R and Das G 2013 Math Anxiety: The Poor Problem Solving Factor in School Mathematics International Journal of Scientific and Research Publications 3 1

[37] Susanti D Waluya S B and Rosyida I 2019 Peran Pembelajaran Mathematical Modeling dengan Pendekatan Open-Ended terhadap Kemampuan Penalaran Matematika PRISMA Prosiding Seminar Nasional Matematika 2 297

[38] Bala A Y and Doğanay A 2014 Improving Primary School Prospective Teachers’ Understanding of the Mathematics Modeling Process Educational Sciences: Theory and Practice 14 1375