Didactic trajectory of learning device development using project-based learning

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Abstract. The purpose of this study is to describe the role of project-based learning in design a learning trajectory of learning device development to improve mathematical knowledge for teaching of prospective mathematics teachers. The method use is design research with three stages, namely, preliminary design; teaching experiment; retrospective analysis. The subjects of research are prospective mathematics teacher class of 2019 from one university in Kuningan, Indonesia. The use of project-based learning in designing learning trajectory of learning device development plays an essential role as an elicited to improve mathematical knowledge for teaching. This study also describes the design principles and characteristics of the learning trajectory namely didactic trajectory designed by the role of project-based learning syntax.

Keywords: Design Research, Learning Trajectory, Mathematical Knowledge for Teaching, Project-Based Learning.

1. Introduction
Professional teachers are teachers who have four teacher competency standards: pedagogic competence, personality competence, social competence and professional competence [1]. Knowledge possessed by teacher influences teacher competence. [2] Suggest that there are two categories of teacher knowledge, namely content knowledge (CK) and pedagogical content knowledge (PCK). Efforts to develop teacher competency in prospective teacher students include content knowledge (pedagogical content) and not only through teacher professional development programs, but also in the lecture process. This is in line with [3] which states that "form her university studies a teacher experiences, actual classroom practice and in-service education interact, influence her beliefs and professional development". Prospective mathematics teacher must learn both aspects namely "mathematics content knowledge" (MCK) and "mathematics pedagogical content knowledge" (MPCK) at the university [3]. MCK and MPCK are aspects of mathematics knowledge for teaching (MKT) [4], [5], [3].

Based on the explanation above, the education process at the tertiary level can ease development of teacher competencies for prospective teachers. Indonesian Directorate General of Higher Education Institution [1] formulated the learning outcomes of mathematics education study programs including: Able to apply didactic-pedagogical concepts and principles of mathematics and mathematics to plan learning by science and technology that is oriented to life skills; Mastering the concepts and didactic-pedagogical principles of mathematics to plan science and technology-based learning [6].
Furthermore [7] states that teachers have four domains of responsibility in making effective learning, 1) preparing learning planning; 2) managing the classroom environment; 3) making conducive learning; 4) professional responsibility. Based on the explanation, the first step to creating effective learning is the teacher must design the learning plan. Therefore, prospective mathematics teacher needs skills in mathematical learning device development, as an effort lesson planning preparation.

MKT is good at supporting the mathematics learning device development activities [8]. MCK capabilities related to mastery of mathematics in-depth, it can ease in developing teaching materials so that mathematical content is easier for students to understand. MPCK's ability is related to Knowledge of curriculum, student characteristics, ability to shape learning goals, ability to decide models and apply the right approach, and good learning assessment knowledge.

Several studies in mathematics education have documented the success of implementing project based learning to improve mathematical abilities [9], [10], [11], [12], [13]. Project-based learning has complex tasks based on questions and problems (problems) that are very challenging and require students to design, solve problems, make decisions, conduct investigative activities, and offer opportunities for students to work independently [14]. So, project-based learning is very suitable in the activities of mathematics learning devices development. Project-based learning is "the instructional strategy of empowering learners to pursue content knowledge or their own and demonstrate their new understandings through a variety of presentation [15]. It can be assumed that project-based learning facilitates improvement the MKT's of prospective teacher.

Based on this background exposure, this study aims to design a learning trajectory for mathematical learning devices development using design research methods to improve MKT for prospective mathematics teacher. In this article presents the answers of research questions, namely "how are the principles and characteristics of the learning trajectory mathematics learning devices development through project-based learning in improving the mathematical knowledge for teaching prospective teacher?"

2. Research Method
This study used design research methods. Design research is right for developing research-based solutions to complex problems in education implements, to develop or confirm theories about the process of learning, environmental learning [16]. Design research consists of three stages of preparation for experiment, experiment teaching, and retrospective analysis [17].

Participants in this study were 24 prospective mathematics teachers at one of the colleges in Kuningan - Indonesia. This study used several research instruments, such as: project worksheets, observation sheets and MKT test. The MKT test used the MKT indicator consisting of 2 aspects of MCK and MPCK. MCK that used cognitive domains are include knowing, applying, and reasoning. MPCK has three sub-domains, namely mathematics curricular knowledge, knowledge of planning for mathematics teaching and learning and Enacting mathematics for teaching and learning [5].

Technique of collecting data used video recordings, observations, interview and MKT tests. Learning video recordings serve to document prospective teacher strategies during the learning process and activities of learning devices development, observation aims to collect data supporting video recordings, MKT tests aims to document the increase in MKT prospective teacher, interviews aim to confirm answers on the MKT test.

Data analysis though retrospective analysis by comparing observation during the learning process with the HLT design. Based on the retrospective analysis researchers can investigate and explain how to improve of MKT through learning trajectory design. Retrospective analysis produces design principles from learning trajectory for mathematical learning device development through project-based learning in improving the MKT of prospective teachers. According to [18] the result of a design research is not a design that works but the underlying principles explaining how and why this design works.
3. Research Results and Analysis

Learning activities start from watching learning video to engagement one of the teacher's tasks, namely developing learning devices, prospective teachers observing learning devices, then lecturers give project questions “learning devices development on quadrilateral”. Lastly, prospective teachers investigate the learning problem of quadrilateral, curriculum, student needs and material of quadrilateral. The Prospective teachers’ making plans and schedules for the project of learning devices development and then prospective teachers developed the learning devices. After that the students validate the learning devices, present and reflect on experiences in the learning devices development activities. As a result, prospective teachers are able to develop valid learning devices and improve their mathematics content knowledge. For more details, researchers will discuss the results of the learning process of the mathematics learning devices development on quadrilateral material, which is divided into three stages are called preparing for the experiment, teaching experiments, and retrospective analysis.

3.1. Preparation for experiment

In this stage, researcher is beginning to implement the idea of mathematics learning devices development by reviewing the literature, conducting observation of learning devices in the student thesis attachment and the ends with designing the hypothetical learning trajectory (HLT). A set of activities for mathematics learning devices development has been designed based on the HLT. The instruction set of activities has been divided into six activities, namely 1) Project question; 2) Preliminary investigation project; 3) Design a plan and schedule for the project; 4) Project design; 5) Assessment of product of project; 6) Evaluate the experience of the project, that have been completed in 14 meetings. Various project activities that make student meaningful learning through project-based learning and ends with the evaluation process.

3.2. Experiment teaching

In teaching experiments, researcher tests the learning activities have been designed in the preparation for experiment stage. There are six activities 1) Project question, engagement and motivation of prospective teacher by watching video of teacher preparation activities in teaching, observation the learning devices, observations of types and forms of the learning devices; 2) Preliminary investigation project, analysis the problem, curriculum, student needs and Quadrilateral material; 3) Design a plan and schedule for the project, planning the learning devices development according to the applicable curriculum and 21st century learning; 4) Project design, development of learning devices (lesson plans, lesson design, evaluation test); 5) Assessment of product of project, validating learning devices, analyzing the results of learning device validation, concluding and revising learning devices according to the validator's suggestions; 6) Evaluate the experience of the project, presentation the result of project and reflection the experience of the learning devices development activities. In each activity the role of the lecturer is as facilitator and motivator in the activities of project question, discussion and percentage of the project learning devices development.

3.3. Retrospective analysis

Researchers design an activity to guide prospective teachers in learning devices development activities. Researchers design activities watching video of teacher's preparation in teaching and learning activities, investigation of learning devices.
From this activity, prospective teachers are given a stimulus through video shows to engage curiosity and motivated in the learning devices development. Prospective teachers' in groups investigate learning devices and lecturers give challenging questions related the project of learning devices development for quadrilateral material. Project of learning devices development are the realistic project. That are challenging to be authentic, prospective teachers choose topics, assignments, work roles, work collaborations, products and product standards that are able to provide challenges for prospective teachers and they can implement projects.

In Figure 2, prospective teachers investigate learning devices and analyze quadrilateral material. From the activities, prospective teachers’ work on projects through investigative activities, investigation of the discovery process, problem solving, design, decision making, model formation of pedagogical and mathematical content knowledge.
In Figure 3, Prospective teachers making plan and schedule of learning devices development activities. Prospective teachers choose and determine the allocation of time, forms of lesson design, models and learning media for learning devices to developed. Prospective teachers complete this activity used pedagogy and content knowledge they obtain from investigative activities.

**Figure 4.** Prospective teachers’ conducted learning device development activities

In Figure 4, Prospective teachers develop the lesson plan, lesson design, learning media for task of learning devices development project through constructive knowledge activities, used pedagogy knowledge and mathematics content knowledge they have.

**Figure 5.** Prospective teachers’ conducted learning device validation activities

In Figure 5, Prospective teachers’ conducted learning device validation between groups. In this activity they provide mutual assessment and input on the learning devices development. in this activity prospective teachers use their pedagogy knowledge and mathematics content knowledge.

**Figure 6.** Prospective teachers’ presentation of learning device products
In Figure 6, Prospective teachers’ presentation of learning device products. In this activity in this activity they explained the learning devices which is a product of the learning devices development project, presented the results of validation and reflected on the experience in the learning devices development activity. All the activity on learning trajectory of learning devices development using project-based learning can improve MKT prospective mathematics teacher. The following is an example.

Figure 7. The results of the pre-test

Figure 8. The results of the post-test

Figure 7 is a pretest answer about applying indicators. The teacher candidate cannot solve the problems correctly. She can only draw the kite and give information the diagonals of kite. Based on the results of the interview, the prospective teacher forgot the area formula of the kite. So she can’t solve the questions given at the time of the pretest. Figure 8 is the answers to prospective teachers at the post-test. She solved the problem by using the concept of rectangular area. The kite is first converted into rectangular shapes and she solves the problem using the concept of the area of a rectangular by making the equation $d_1$ is the length of the rectangular and $\frac{1}{2} d_2$ is the width of the rectangular. Thus, Prospective teachers can solve the problems correctly.

Based on the explanation above, it appears that learning devices development activities through project-based learning has the important role in improvement the motivation of prospective teachers in learning devices development activities and improve the MKT of prospective teachers. Other than that, activities designed to create prospective teachers’ discovery the concept of quadrilateral through investigate and construction activities. So that learning supports and provides the experience of prospective teachers in the process of learning devices development. The following is an example of a quadrilateral material investigation worksheet and an example of the results of lesson design which is one of the learning devices developed by prospective teachers.
Didactic trajectory is the principles of learning trajectory design on a topic [17]. Design principles are heuristic statements based on input or suggestions based on research to solve a problem [14]. The statement always develops in certain situations and does not guarantee success in other situations. Therefore, to generate a didactic trajectory, all activities that are designed and implemented in a study must be documented and analyzed retrospectively [17]. The following is a didactic trajectory on mathematics learning devices development through project based learning.

Based on analysis retrospective, didactic trajectory of mathematics learning devices development through project-based learning is the principles of project-based learning trajectory in the course of developing mathematics learning devices to achieve learning goals, namely the increase of MKT prospective teachers through activities in 14 meetings. Didactic trajectory of learning devices development developed based on the principles of project-based learning that aims to improve MKT of prospective teacher. The principles are: 1) Centralism, the exist project tasks in each meeting in the learning trajectory developed, broadly in the learning trajectory developed divided into two projects namely preliminary projects (knowledge of the design of purchasing devices, teaching materials, chains, models and learning media, teaching materials and their types) and development project (planning of design and development of mathematical learning devices to get valid learning devices). 2) There are driving questions in each activity that can encourage prospective teachers to struggle to get the concept or main principle of a particular concept. Submitting questions by linking conceptual knowledge with real activities is an external motivation that is able to arouse the internal motivation of prospective teachers in working on project tasks. 3) Investigation, prospective teachers work on projects through investigative activities, investigation of discovery processes, problem solving, design, decision-making, model formation. 4) Constructive, activities to complete the project through constructive knowledge activities. 5) Realistic (realism), projects that are real challenges that are challenging to authentic, so to pick out topics, assignments, work roles, work collaboration, products and product standards able to give challenges for prospective teachers and prospective teachers can implementation the project. [14], [19], [20], [21], [15], [22], [23].

In addition to the principles of project-based learning to improve MKT above, there are several didactic trajectory characteristics that are developed to improve MKT. These characteristics are (1) Prospective teachers' as learning center. (2) the lecturer as a facilitator who guides project investigation; (3) There are problems whose solutions aren't predetermined; 4) Prospective teachers' make decisions and make work steps; 5) Prospective teachers' design processes to achieve results; 6) Classes have an atmosphere that tolerates mistakes and changes; 7) Prospective teachers' are
responsible for obtaining, processing information collected; 8) Prospective teachers' play an active and responsible role in developing mathematics learning tools; 9) Prospective teachers' regularly look back on what they are doing, there is a continuous evaluation by the lecturer 10) The final results are products and evaluation of product quality.

4. Conclusion
This study develops the learning trajectory of learning devices development using project-based learning to improve MKT prospective mathematics teacher. The product of this study is a didactic trajectory for mathematical learning devices development that provides learning to improve the MKT of prospective mathematics teacher. Prospective teachers experience MCK and MPCK, they improve after following the activities in design of learning trajectory of project-based mathematics learning devices development.

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