Experiences of Pre-Service Teachers' on Skill-Based Problem Solving Oriented Lesson Study

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Abstract
This study aims to present the experiences of pre-service mathematics teachers' on skill-based problem solving-oriented lesson study. In the study, the activities related to the learning environments designed by the lesson study groups before and after the research lesson with a focus on problem solving are investigated. In this way, the study aims to reveal how lesson study affects pre-service mathematics teachers' awareness of teaching problem solving. In the study, 31 pre-service mathematics teachers first received a comprehensive training on teaching problem solving in mathematics for six weeks. Then, the pre-service teachers received a one-week training on the lesson study professional development model. In the last stage, they carried out problemsolving-focused lesson study processes under the guidance of the researcher with ten lesson study groups that they formed on the basis of volunteerism. Finally, the lesson study groups shared their experiences with the other pre-service teachers participating in the study by presenting the bulletins they prepared. The data were obtained through planning and evaluation meeting minutes, observation notes of research lesson practitioners and observers, initial and final lesson plans and documents. The data obtained in the study, in which the case study design of the qualitative research approach was preferred, were subjected to descriptive analysis using Polya's (1957) problem solving process steps framework. During the lesson study process that they experienced within the scope of the research, pre-service teachers shared their knowledge and experiences about the problem solving process and teaching with each other, as well as activities such as collaborative work in groups, designing and implementing teaching materials such as lesson plans and worksheets. According to the results obtained in the study, it was seen that the activities in the problem solving-oriented learning environments of the pre-service teachers varied thanks to the collaborative structure of the lesson study. In addition, it was seen that the pre-service teachers had the opportunity to experience the steps of the problem solving process and the instructions they could use in these steps on the students through the research lesson and then make the necessary rearrangements through evaluation meetings. Considering the opportunities offered by the collaborative and school-based structure of lesson study, it is thought that lesson study can be a functional model for pre-service teachers to use theory and practice together in courses on problem solving instruction.
Keywords: Lesson Study, Skill-based Problem, Teacher Education.

Introduction

The rapidly changing and evolving profile of people in the world also affects the ideal student and therefore teacher profile, educational policies, systems and components of the systems. The education policy makers of countries evaluate the suitability of their students to the developing and changing human profile by focusing on the scores obtained in national and international exams and make the necessary moves in their education systems in the light of these evaluations. In Turkey, low student achievement in international exams for the last 20 years has led to the inclusion of skill-based problems in the curriculum (Arslan, 2022). Skill-based problems, which are one of the most important parts of the renewed education system in Turkey in 2018, have started to be included in school courses, books and central exams in order to measure students' high-level skills such as reading, reading comprehension, interpretation, inference, problem

solving, analysis, critical thinking, logical inference, reasoning, and scientific process skills (Arslan, 2022; Karakeçe, 2021). The present study reflects a part of a large-scale research carried out in cooperation with the national education directorate-university, which was initiated with the question of whether lesson study can be a functional tool in the process of incorporating skill-based problems into learning environments, which has been on the agenda since 2018 in Turkey. In addition to reflecting the lesson study practices carried out by pre-service teachers within the scope of a course on teaching problem solving, the research also includes suggestions on teaching the problem solving process.

Skill-Based Problem

Skill-based problems (Arslan, 2022; Gürbüz, 2014), which came to the agenda as a result of the failure of students in national and international exams in Turkey (Çepni, 2019; Gürbüz, 2014), are in line with the questions of national and international monitoring exams in accordance with the purpose of their emergence. In the literature, there are many studies linking skill-based problems with the problems used in PISA, which triggered their emergence (Gürbüz, 2014; Kertil et al., 2021). From this point of view, skill-based problems introduced by the Ministry of National Education have also changed the image of the ideal mathematics question adopted in the past. Skill-based problems contain a context supported by components such as written material, graphics, tables, charts, maps, pictures or diagrams, and include open-ended questions that require students to use higher-order skills such as interpretation, analysis, problem solving and mathematical reasoning (Arslan, 2022; Kertil et al., 2021; Miller et al., 2009; Sanca et al., 2021). Based on these characteristics, in order for students to solve skill-based problems, they should not only know mathematics well, but also be able to use mathematics in different contexts such as daily life and different disciplines. Therefore, it can be stated that skill-based problems are also context-based. Context-based problems are problems related to daily life that require students to analyse and evaluate concepts, and that can be in daily life that enable students to remember their previous knowledge based on facts (Samo et al., 2017). Skill-based problems not only change the usual mathematical questions, but also support students to have different experiences about mathematics and the nature of mathematics. Skill-based problems help children learn mathematics without having to memorise mathematical rules, terms or formulas and then remember them (Arslan, 2022; Sanca et al., 2021).

It is thought that it is important to find answers to questions such as how skill-based problems can be used in the classroom environment and the characteristics of learning environments where skill-based problems are used. In this context, it can be stated that it is important for teachers and mathematics learning environments to describe the lesson study processes of pre-service teachers who will use skill-based problems in their classrooms with a focus on designing a learning environment for skill-based problem solving. Based on this judgement, the lesson study model, which has been widely used in teacher training and development in recent years, was used in the study (Fernandez & Yoshida, 2004; Dudley, 2014; Lewis, 2002; Widjaja et al., 2021).

Lesson Study

Lesson study is used in teacher training and development as well as in the process of conducting and evaluating the educational reforms implemented by countries (Lewis & Takahashi, 2013). Lesson study process, which includes plan, implement-observe, and evaluate actions in essence, has been explained in different dimensions by different researchers (Baba, 2007; Kanbolat & Arslan, 2022; Murata, 2011). It can be seen that lesson study represents a scientific research process from determining the goal to the evaluation of the learning environment. The participants, who transform the classrooms into laboratories, examine the learning environment designs they have prepared together by subjecting them to experimentation and observation in the classroom laboratory. If the learning environment they have designed does not yield the desired results, in other words, if ideal learning is not realised, they go back to the beginning and design new learning environments, experiment and share their results (Kanbolat & Arslan, 2022).

Lesson study has a cyclical structure and the process of lesson study is described differently by different researchers (Dudley, 2014; Fujii, 2016; Murata, 2011). The lesson study process adopted in the research was designed and conducted inspired by Fujii (2016) presented in Figure 1.

Figure 1 Lesson Study Process (Fujii, 2016)

As can be seen in Figure 1., the lesson study process starts with the lesson study group setting a common goal. The whole lesson study process is carried out towards the determined goal (Cerbin, 2011; Lewis & Hurd, 2011; Murata, 2011; Stepanek et al, 2007). This goal can be a specific situation such as eliminating a misconception, changing attitudes towards a course, or it can be a situation that affects a wider audience, such as developing an educational reform of a country or implementing a new teaching approach. Then comes the step of planning the research lesson by sharing the knowledge, opinions and experiences of all group members (Fernandez & Yoshida, 2004; Fujii, 2016; Murata, 2011; Stigler & Hiebert, 1999). All the details about the research lesson are discussed by the members and activities and precautions for all possible or unexpected situations are taken into consideration. The lesson plan is realised by a member of the group and the other group members observe the lesson simultaneously in the classroom (Fernandez & Yoshida, 2004; Fujii, 2016; Murata, 2011; Stigler & Hiebert, 1999). Finally, in the reflection step, the lesson study group shares their evaluations and criticisms about the lesson (Fernandez & Yoshida, 2004; Fujii, 2016; Murata, 2011; Stigler & Hiebert, 1999). They revise the missing or defective parts of the plan and thus finalise the plan. Lesson study groups can share their experiences and products with other lesson study groups through newsletters Dudley, 2014; Fernandez & Yoshida, 2004; Stepanek et al., 2007; Stigler & Hiebert, 1999). In this context, the last invisible step of lesson study can be considered as the sharing step.

This study reflects a part of a large-scale research carried out in cooperation with the national education directorate-university, which was initiated with the question of whether lesson study can be a functional tool in the process of incorporating skill-based problems into learning environments, which has been on the agenda since 2018 in Turkey.

Purpose of the Study

The aim of the study is to present the experiences of pre-service mathematics teachers' on skill-based problem solving-oriented lesson study. In line with this purpose, the sub-problems of the study are presented below:

- How is the design of pre-service teachers' problem solving-oriented learning environments before the research lesson?
- What kind of rearrangements did the pre-service teachers make in their problem solving-oriented learning environments after the research lesson?

Methodology

Research Design

In the study, the case study design of the qualitative research approach was employed in the research since the experiences of the pre-service teachers in the lesson study conducted for skill-based problems will be reflected in detail as it is (Creswell, 2007; McMillan, 2004).

Sample of the Study

The sample of the research consists of 31 pre-service teachers studying in the elementary mathematics teaching programme of a state university located in a medium-sized province of Eastern Anatolia and taking the problem solving course in mathematics. The sample was determined through convenience sampling in order for the pre-service teachers to carry out the lesson study process completely voluntarily and effectively. There are 31 pre-service teachers working in 10 lesson study groups in the study. In the research, the groups to

which the pre-service teachers who experienced the process in the form of lesson study groups are shown as G1, G2, G3, ..., G10, and the presentation of the pre-service teachers is shown as G1.1.; G1.2.; G1.3. by using the names of the groups they are involved in and the randomly determined sequence numbers, for example, if the 1st group consists of three pre-service teachers, the 1stpre-service teacher is shown as G1.1.; 2nd pre-service teacher as G1.2.; 3rd pre-service teacher as G1.3.

Research Process

The research process can be considered in three dimensions. In the first stage of the research, pre-service teachers received a comprehensive training on teaching problem solving in mathematics for six weeks. Then, the pre-service teachers received a one-week training on the lesson study professional development model. In the third stage, they carried out skill-based problem solving-oriented lesson study processes under the guidance of the researcher with the lesson study groups they formed on a voluntary basis and shared their experiences with all the pre-service teachers participating in the study.

Skill-based problem solving-oriented lesson study practices: Pre-service teachers formed ten different lesson study groups of three or four people on a voluntary basis. The formed Lesson Study groups conducted the Lesson Study processes by holding meetings with the researcher as an external expert in two-hour periods every week. Some groups held additional meetings if they needed and the researcher as an external expert took part in these meetings upon their request. The pre-service teachers carried out the lesson study processes in the groups they formed according to Fujii's (2016) description of the lesson study process. In Figure 2. below, the lesson study processes of the pre-service teachers are visualised and presented.

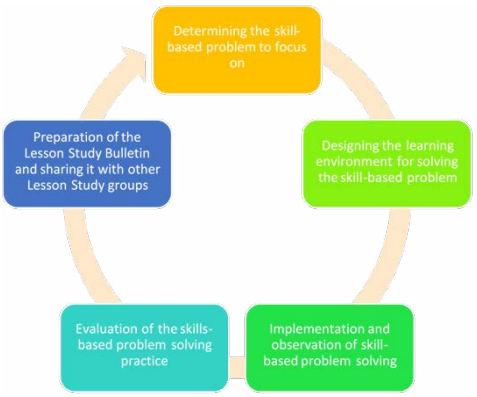

Figure 2 Lesson Study Process for Skill-Based Problem Solving

Determining the Skill-based Problem to Focus on

After the pre-service teachers formed their lesson study groups, they started the process of determining the skill-based problem to focus on. Each pre-service teacher participated in the meeting with two problem proposals by utilising the course materials published or recommended by the Ministry of National Education. Thus, in this meeting, the lesson study groups selected one of the proposed 6-8 skill-based problems worth working on in the lesson study.

Designing the Learning Environment for Solving the Skill-based Problem

In this step, the pre-service teachers discussed the decisions about how to solve the selected skill-based problemwith the students in the classroom environment. Based on Polya's (1957) problem solving process framework, they discussed what kind of activities they would do in each of the steps of understanding the problem, determining the strategy, solution and evaluation of the solution and prepared lesson plans at the end of the meeting. Finally, one of the pre-service teachers was selected to implement the prepared lesson plan in a real classroom environment.

Implementation and Observation of Skill-Based Problem Solving

The selected pre-service teacher applied the prepared lesson plan in the real classroom environment and the other lesson study group members observed this application and wrote their observation notes

on the lesson plan. After the implementation, the teacher candidate who applied the plan also recorded his/her comments and suggestions about the plan in writing on the lesson plan.

Evaluation of the Skills-based Problem Solving Practice

Lesson study group members held a meeting to discuss the strengths and weaknesses of the implemented lesson plan. Firstly, the pre-service teachers who carried out the implementation and then the observing pre-service teachers shared their opinions and suggestions. Decisions were taken about the sections that needed to be rearranged in the plan and how these sections would be arranged. The decisions taken were transferred to the rearranged lesson plan. As a result, a more ideal learning environment design example was obtained.

Preparation of the Lesson Study Bulletin and Sharing it with Other Lesson Study Groups

Lesson study groups shared their lesson study experiences focused on skill-based problem solving with other lesson study groups during 40-minute meetings.

The lesson study process depicted in Figure 2. was carried out simultaneously by 10 lesson study groups under the guidance of the researcher. Each lesson study group shared their bulletins describing the process they experienced with the other groups.

Data Collection and Data Collection Tools

As required by the case study design (Creswell, 2007), more than one data collection tool was used in the study. The data related to the lesson study process were obtained through the bulletins prepared by the lesson study groups. The data were obtained through the planning and evaluation meeting minutes in the bulletins, observer and practitioner pre-service teacher observation notes of the research lesson, initial and final lesson plans and documents.

Meeting Minutes

They consist of the minutes of the meetings held by the Lesson Study groups for the processes of selecting the skill-based problem to be focused on, designing and evaluating the learning environment for the solution of this problem.

Pre-Service Teacher Observation Notes

They consist of the observation notes taken by the observer pre-service teachers and the practising pre-service teachers during the implementation phase of the lesson study.

Lesson Plans

They consist of the initial and final versions of the lesson plans prepared by the lesson study groups during the process.

Documents

Documents such as resources used in the lesson study process, skill-based problem situations, worksheets prepared were also used to support the findings obtained in the research.

Data Analysis

Polya's (1957) problem solving process steps were taken into consideration in the analysis of the data. The data of the learning environments designed in the lesson study planning and evaluation meetings were analysed by dividing them into the steps of understanding the problem, determining and implementing the strategy, and evaluating the solution. The data obtained were coded simultaneously with an expert in the field of teacher training and qualitative research. In order to increase the reliability of the research, simultaneous coding method was used and consensus was reached on the categories where there was no consensus.

Role of the Researcher

The researcher played the role of an external expert by drawing on her past experiences of lesson study and her knowledge of the literature in order to arrange, create and conduct the lesson study process. In addition, the researcher participated in the lesson study meetings in the context of problem solving in mathematics when needed by the lesson study groups and participated in the process as an external expert to support them as a member of the group. The researcher also supported the lesson study groups in terms of accessing the resources or materials needed by the lesson study groups during the process, reaching a common decision, and producing solution proposals. Finally, the researcher

also supported the groups in the process of creating lesson study bulletins.

Results

In this section, the learning environment designs of the lesson study groups before the research lesson and the revisions of the learning environment designs of the lesson study groups after the research lesson are presented under the two headings in order to present the problem solving-oriented lesson study experiences of the pre-service teachers.

Learning Environment Designs of Lesson Study Groups before the Research Lesson

The findings obtained from the data are presented under the headings of findings related to the steps of understanding the problem, determining the strategy, implementing the strategy and evaluating the solution.

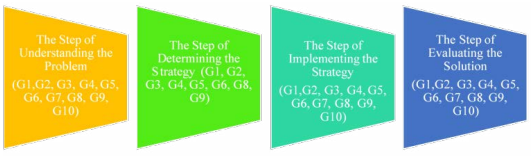

Figure 3 Learning Environment Designs of the Lesson Study Groups Before the Research Lesson

As can be seen from Figure 3, all of the lesson study groups designed activities related to the steps of understanding the problem, implementing the strategy and evaluating the solution in their learning environment designs. It is noteworthy that the groups coded G7 and G10 did not design any activity related to the step of determining the strategy.

Findings Related to the Step of Understanding the Problem

When the research lesson designs of the lesson study groups were analysed in the dimension of understanding the problem, it was seen that the pre-service teachers included different types of activities.

The groups coded G1, G5, G6, G9 and G10 used *additional materials such as videos, visuals or presentations in addition to student knowledge and experiences related to the context in order to familiarise students with the context of the problem and attract their attention.* For example, in order to make the *'Vehicle licence plate'* problem, which includes the rule that vehicle licence plates are given to vehicle owners, more understandable by the students, the G10 group watched a video about vehicle licence plates before presenting the problem to the students.

> *"Students' attention was drawn to the context of the problem by watching a video about the licence plate recognition system of vehicles. Vehicle number plates were explained by likening them to identities. Thus, the practitioner teacher drew the students' attention to themselves. Since our problem was about the processing of number plates, after watching the video, students were asked questions about what the number plates were given according to. Especially the meaning of the "TR" symbol on the number plates was immediately noticed by the students. It was noticed by the students that the colours of the number plates vary from country to country just like the symbols on the plates. It was emphasised that the letter code in the middle changes alphabetically. In the process carried out in a question and answer manner, the teacher determined the students' readiness levels related to the context of the problem."* [G10. 2nd coded pre-service teacher research lesson observation note]

An example of this action of the groups coded G5, G7, G8, G9 and G10, who preferred to read the problem with the class by emphasising important places, is given below.

> *"I distributed the worksheets and first had another student read the problem. Then I read it again aloud, describing and emphasising it."* [G5.1. coded pre-service teacher practitioner research lesson observation note]

The groups coded G3, G4, G5 and G7 carried out activities for students to identify the expressions that are important for the solution of the problem in the step of understanding of the problem.

> *"With the question 'Which of the information given to you when you read this problem is necessary for the solution of the problem according to you?', students are asked to understand the problem better and find out which information is necessary for them to solve the problem."* [G3 plan meeting minutes]

The groups coded G1, G2, G7 and G9 preferred to carry out activities related to decomposing and interpreting the problem in the step of understanding

the problem. An example of such an application related to the problem statement 'Jumping frog' is presented below.

"The students were asked 'What is the information given about the movements of frogs?' and 'What does the expression 'three frogs' eachmean?' and 'How should the frogs be placed on the stones?'." [G2.1. coded pre-service teacher research lesson observation note]

The groups coded G5, G8 and G9 asked the students to express the problem in their own sentences in the step of understanding the problem. For example, the observation note of the group coded G8 is presented below.

"After the students concentrated on the question a little more, the teacher read the problem once and then read the important parts more emphatically in the second reading. Then the teacher asked the students what they understood from the problem and asked them to express the problem in their own words. After receiving feedback from the students, she/he corrected some of them and added some others." [G8.2. coded pre-service teacher research lesson observation note]

In the step of sharing the problem with the students, the groups coded G7, G9 and G10 first distributed the worksheets to the students and then gave a certain amount of time for the students to read the problem silently individually. The observation notes they took about the situations they observed during this process and examples of reflection statements about the situations they noticed are given below.

"[...] we asked the students to read the problem internally [...] our aim was to find out whether the students could understand the questions when they read them. We realised that some students read it at first and underlined the important parts of the question, while some students did not want to read it because they considered the question too long verbally." [G10.1. coded pre-service teacher research lesson observation note]

Groups G6, G7 and G8 aimed to support students' readiness about the mathematical content related to the problem in the step of understanding the problem. The observer note of the implementation carried out by the G7 group for this purpose is as follows.

"The teacher showed a video about angles and then gave information about problem solving appropriate to the 8th grade level.[...]" [G7.2. coded pre-service teacher research lesson observation note]

The groups coded G1 and G3 provided guidance to make the students realise the relationship between the variables in the problem.

"When you look at the number of glasses in box 1, box 2 and box 3, how does the number of glasses in each box differ from the number of glasses in the previous box? [...] It is checked whether the students realise the existing relationship by considering the given conditions." [G3 plan meeting minutes]

The groups coded G8 and G10 asked the students to identify what is given and what is required in the problem.

"The questions of 'What is given in the problem and what does the problem want from us?' are asked to the students." [G8 plan meeting minutes]

It is seen from the findings presented above that almost all of the lesson study groups designed more than one activity for the step of understanding the problem in their learning environments.

Findings Related to the Step of Determining the Strategy for Solving the Problem

The groups coded G1, G2, G3, G4, G5, G6 and G8 designed their learning environments by focusing on the strategy of establishing relationships and relations in the process of solving the problem they chose.

"'Did you notice how the increase in the number of glasses changes as the box number increases? Explain this change.' With these questions, it is aimed that the students write the relation they find according to which rule the terms of the pattern continue with their own expressions." [G8 plan meeting minutes]

Groups coded G1, G2 and G4 used the strategy of using similar simple problems in the problem solving process. The meeting minutes of the G1 group regarding the solution of the problem they used about the chair grabbing game are presented below as an example.

"The step of determining the strategy is applied with the questions on the worksheet: 'How would we proceed if the question was asked with two frogs instead of three frogs?' 'How can the student express the number of steps changing according to the number of frogs?' " [G2 plan meeting minutes]

The groups coded G1, G3, G5 and G6 used the table making strategy. For example, the explanation of group G3 on how they will use the table-making strategy is given below.

"Students are asked to fill in the table given in accordance with the table making strategy for the solution of the problem. Here, students are expected to fill in the table according to the relationship between the box number and the number of glasses. It is ensured that they analyse the data more clearly in the table." [G3 plan meeting minutes]

The questions asked by the group coded G1 in order for them to recognise and choose the strategies of making a list, creating a table or making a relationship for solving the problem are presented below.

"'When the music stops for the first time, how many students sit on the chair?'; 'When the music stops for the second time, how many students sit on the chair?'; 'When the music stops for the fifth time, how many students sit on the chair?'. With these questions, it is aimed that the student reaches a generalisation about the solution of the problem by using the strategies of making a list, creating a table or making a relationship." [G1 plan meeting minutes]

The group coded G9 used the instructions related to the step of understanding the problem and evaluating the solution in the step of determining the strategy.

"'What does it mean for you that Semih divides the gold into 3 equal parts and takes the remaining 1 gold?'; 'What does it mean for the number of gold in the pouch that 3 friends can divide the gold into 3 equal parts after waking up and there is no gold left in the pouch?' and 'If the number of gold in the pouch was known after 3 friends woke up, what kind of a path would be followed?'. We decided to use these questions in the step of determining the strategy." [G9 plan meeting minutes]

Based on the findings presented above, more than half of the lesson study groups planned activities to direct students to more than one strategy for solving the problem. In addition, it is seen that the groups coded G7 and G10 did not plan any activity related to this step.

Findings Related to the Step of Implementing the Strategy

The groups coded G1, G2, G3, G4, G5, G6, G7, G8 and G10 directly asked what was asked in the problem in the step of implementing the strategy.

"'Did we find a rule for the number of steps varying according to the number of frogs? If we did, what is this rule?'. With this question, the step of implementing the strategy was addressed." [G2 plan meeting minutes]

The observation note of the activity carried out by the group coded G9 for applying the backward working strategy is given below.

"We aimed to make students realise the steps of solving the question step by step with the questions of 'What is the number of gold in the final situation?', 'What is the number of gold before taking life?', 'What is the number of gold before taking Furkan?', and 'What is the number of gold before taking Semih?'. We see that the 8th grade students reached the solution in this section and wrote down what was asked for each step." [G9.1. coded pre-service teacher research lesson observation note]

Findings Related to the Step of Evaluating the Solution

The groups coded G3, G4, G6, G7, G8, G9 and G10 performed this stepby having them solve another problem they generated from the problem.

"After solving the problem, students are asked to solve another problem similar to the problem. For this, the students are asked to solve another problem similar to the problem on the worksheet: 'Can you find whether the lighting of the cards in the quadratic region is on or off at any minute? For example, can you find which cards in the quadratic region have their lights on/off at the 32nd minute? Explain.' and they are expected to solve this question." [G6 plan meeting minutes]

Groups coded G1, G2, G3, G7, G9 and G10 preferred to make practices related to evaluating the strategy used to solve the problem in this step:

"At the end of the time allocated for solving the problem, students are asked how they think and which strategies they use to solve the problem. In this way, a discussion environment is created by taking different ideas in the classroom environment. With the feedback from the students, the focus is on solving the problem, so it is checked whether they use appropriate strategies. Students are evaluated according to the strategies they use." [G1 plan meeting minutes]

The groups coded G1, G2, G4 and G5 preferred to carry out a new problem-posing activity inspired by the problem.

"We asked students to design a new and original problem with the statement 'Based on this information, write a new problem.'." [G5 plan meeting minutes]

The group coded G3 and G7 stated that they carried out activities to ensure the correctness of the solution of the problem.

"The results are analysed for accuracy and where they are not clear or where mistakes have been made. Any misconceptions are eliminated." [G3 plan meeting minutes]

The group coded G2 completed the step of evaluating the solution of the problem by having the students play a virtual game of the problem.

"Finally, after solving the problem, when the frog jumping game started to be played, I saw that the students were very eager. I noticed that even the students who did not participate in the problem solving process wanted to go up to the board to try it." [Observation note of observer pre-service teacher coded G2.2.]

The group coded G8 planned to go back to the step of understanding the problem.

"For students who cannot solve the problem and have difficulties in understanding the solution of the problem, we go back to the step of understanding the problem." [G8 plan meeting minutes]

The group coded G10 planned to complete the step of evaluating the solution by evaluating the problem solving process.

"After the solution of the problem is reached, it is discussed in the class about which steps and strategies they used while solving the problem." [G10 plan meeting minutes]

Based on the above findings, it can be said that almost all of the groups designed more than one activity related to the step of evaluating the solution of the problem.

Revisions in Learning Environment Designs of Lesson Study Groups after the Research Lesson

In this section, the findings obtained from the data are presented under the headings of findings related to the steps of understanding the problem, determining the strategy, implementing the strategy and evaluating the solution.

Figure 4 Learning Environment Revisions of the Lesson Study Groups After the Research Lesson

As it can be seen from Figure 4 the lesson study groups mostly needed to make revisions in their learning environment designs regarding the step of understanding the problem.

Findings Related to the Step of Understanding the Problem

In the step of understanding the problem, groups G2, G3, G5, G6, G7, G8 and G9 made revisions to add activities for determining important expressions in the problem. For example, the revision of the G2 group about the 'jumping frog' problem they worked on is related to the use of figure diagram drawing as well as determining the important expressions in the problem.

"[...] in order to make the problem more understandable, it was decided that the teacher should ask questions such as 'What is the information given to you in the problem that you think will help you in solving the problem?' and 'How should the frogs be placed on the stones? Let's draw'." [G2 evaluation meeting minutes]

Group G7 moved the instruction in the step of understanding the problem to the step of evaluating the solution.

"It was decided to move the instruction 'If you wanted to create a polygon of your own, what kind of changes would you make with the slats?', which was included in the step of understanding the problem, to the step of evaluating the solution." [G7 evaluation meeting minutes]

The G9 group made changes to make the instructions in the worksheet more understandable by the students.

"In the worksheet in the research lesson, we observe that most of the students could not understand the instruction of 'What is intended to be explained in the question given to you in the worksheet in the research

lesson? Explain.' and could not make a mathematical interpretation that would lead to a solution. When the teacher, who realised this in the lesson, directed this instruction as 'What is the problem situation?', and the students easily understood the instruction and were able to answer it. Therefore, we decided to change this instruction in the worksheet." [G9 evaluation meeting minutes]

Findings Related to the Step of Determining the Strategy for Solving the Problem

Groups G2 and G6 made revision decisions regarding the step of determining the strategy in their lesson plans and worksheets.

The group coded G2, which utilised similar simple problems in the problem solving process, decided to add new antecedent instructions to the worksheets related to this step after the research lesson.

"[...] It was decided that the teacher would perform the transition to the strategy determination step more ideally with the question 'How do we express the process of displacement of one and two frogs? Show it visually.' It was decided that the transition to the strategy determination step would be more ideal." [G2 evaluation meeting minutes]

The group coded G6 stated that they decided to write the instructions in the worksheet in a more understandable way for the students.

"After the implementation, we observed that some of the instructions we planned for determining the strategy were difficult for the students to understand. For this reason, we rearranged the instructions to be used by the teacher in this context." [G6 evaluation meeting minutes]

Findings Related to the Step of Implementing the Strategy to Solve the Problem

It is seen that G1, G2 and G3 groups made revision decisions regarding the step of implementing the strategy. The G1 group, which used the table making strategy, made a decision about the students filling the table in the worksheet.

"It was decided to leave the 2nd and 3rd columns of the table blank so that the students could fill in the table [the table presented as filled in the worksheet in the first application] and thus realise the strategy to be applied." [G1 evaluation meeting minutes]

The G2 group indicated the changes related to the instructions they added to the worksheet in their minutes.

"[...] We made the step of implementing the strategy more understandable with the questions: 'How many steps did you change the frogs in the game you played?'; 'Show the number of steps changing according to the number of frogs in the table.'; 'Did you find any relationship or rule for the number of steps changing according to the number of frogs?' " [G2 evaluation meeting minutes]

The G3 group decided to use games in the implementation step of the strategy.

" [...]In order to understand the implementation stepof the strategy more clearly and to increase attention to the problem, we should gamify the problem and apply it in the classroom." [G3 evaluation meeting minutes]

Findings Related to the Step of Evaluating of the Solution

After the research lesson, the groups coded G1, G2, G3 and G7 needed rearrangements in their learning environments related to the step of evaluating the solution of the problem.

In the research lesson, the group coded G1, who encountered the students' request for additional explanation for the instruction in the worksheet, rearranged the instructions.

"Finally, we asked the students to create their own problems. When the students saw this question, they asked questions such as 'Can we change the rules?'. There was no statement in our plan to give an explanation on this issue. Some of the students changed only the numbers and rules, some students changed both the rules and the numbers, and some students even added different variables such as time to the problem. Some students also completely changed the setup and set up a problem on a different topic. I think our instruction should be rearranged." [G1.3. pre-service teacher practitioner research lesson observation note]

Considering the situation described in the observation note, G1 modified the instruction in the worksheet as explained below.

"Students could not understand the statement 'Let's try to create a new problem using this problem.'. In order to make the statement more understandable, the statement was rearranged as 'Let's try to create a

new problem using this problem. You can change the numbers and rules in the problem.' " [G1 evaluation meeting minutes]

Prior to the research lesson, the group coded G2, which gave different solution methods and activities for constructing new problems inspired by the problem together in a single instruction, decided to write the instruction they used after the research lesson in a more understandable way for the students and rearrange it into two separate instructions.

"[...] 'Which ways did you use while solving the problem?' and 'What kind of changes can you make in the problems given to you to construct a new problem? (Write the problem you constructed.)' These questions were arranged as two separate instructions for the step of evaluating the solution of the problem" [G2 evaluation meeting minutes]

The group coded G3 decided to rearrange this instruction after the research lesson because they realised that the instruction they used for the step of evaluating the solution of the problem in the research lesson was a difficult instruction for the students to answer.

"Students could not answer the question 'If the question had started with 3 cups in the 1st box instead of 1 cup in the 1stbox, how do you think our answer would have changed?'. The reason for this was that we did not define an upper limit for the number of boxes. Therefore, the students could not answer the question 'If the question was started by arranging 3 glasses in the 1st box instead of 1 glass in the 1st box without changing the pattern rule, how many glasses would be needed for the 12th box? How do you think there would be a change in our answer?' and it was decided to deepen the stepof evaluating the solution." [G3 evaluation meeting minutes]

The group coded G7 realised that an instruction that they included in the step of understanding the problem in the research lesson should be included in the step of evaluating the solution and made arrangements accordingly.

"It was decided to move the instruction 'If you wanted to create a polygon unique to yourself, what kind of changes would you make with the slats?', which was included in the step of understanding the problem, to the step of evaluating the solution." [G7 evaluation meeting minutes]

Discussion, Conclusion and Suggestions

In the step of understanding the problem, in addition to students' knowledge and experience about the context, the pre-service teachers designed and carried out activities of using additional materials such as videos, visuals or presentations, reading the problem with the class by emphasising the important parts of the problem, enabling students to identify the statements that are important for the solution of the problem, breaking the problem into parts and interpreting it, enabling students to express the problem with their own sentences, enabling students to read the problem silently individually, supporting students' readiness about the mathematical content related to the problem, making students realise the relationship between the variables in the problem and determining what is given and desired in the problem. It is noteworthy that the pre-service teachers preferred a variety of activities related to the step of understanding the problem and almost all of the lesson study groups preferred to use more than one activity in this step in their plans. In addition, half of the groups designed different activities at the problem comprehension step in order to ensure that the students were familiar with the problem context before sharing the problem with the students. Based on this result, it can be stated that pre-service teachers attach importance to students' mastery of the context for the step of understanding the skill-based problems. The importance of the context of the problem is also seen when the PISA problem solving process assessment framework, which is the source of skill-based problems, is analysed. In addition, due to the contextual structure of skill-based problems, it has been stated by other studies that it is important to help students remember their experiences and use contextual clues in solving such problems (Cumming & Maxwell, 1999; Davis, 2017; Dinç Artut & Ildiri, 2013). In the step of understanding the problem, another activity preferred by half of the lesson study groups was reading the problem aloud with emphasis. This preference may be based on the fact that the textual structure of skill-based problems is longer than the usual problem types. As a matter of fact, PISA questions, which are identified with skill-based problems, state that the main reason for failure in mathematics is that written texts are

not understood by students (Donolato et al., 2019). Polya (1957) stated that the step of understanding the problem is the first and one of the most important steps of the problem solving process. Therefore, it is thought that the pre-service teachers may have concentrated on this step more than the other steps based on the fact that it is important to understand the problem correctly in order to enable students to reach the solution of the problem in skill-based problems. Another result obtained about the step of understanding the problem is that after the research lesson, pre-service teachers mostly applied for revision related to the step of understanding the problem.

In the steps of determining and implementing the strategy, it was found that the lesson study groups arranged instructions for using strategies such as establishing relationships, using similar simple problems, making tables, making lists and more than half of the groups directed the students to more than one strategy for solving the problem. This may be due to the fact that skill-based problems address students' metacognitive skills. As an antecedent of metacognitive behaviours such as searching for alternative solutions, rationalising solutions or analysing solutions in Eric and Mansoor's (2007) Cognitive-Metacognitive Problem Solving Taxonomy, pre-service teachers may tend to direct students to more than one strategy. Indeed, it is known that pre-service teachers' decisions to include different ways of solving problems are important and necessary for students to have successful problem solving experiences (Youngs et al., 2022). In addition, the result that some groups did not plan any activity related to this step is also important. It is seen that almost all of the lesson study groups related to the step of implementing the strategy performed the step of implementing the strategy by using the desired statement in the problem and only one group actually used instructions for the step of implementing the strategy.

In the step of evaluating the solution of the problem, the pre-service teachers designed and implemented the following activities: having the students solve another problem generated from the problem; evaluating the strategy used to solve the problem; constructing new problems with the students inspired by the problem; verifying the accuracy of the solution of the problem; playing a virtual game of the problem to the students; returning to the step of understanding the problem and evaluating the problem solving process. In addition, it is noteworthy that more than half of the lesson study groups applied practices for problem posing and strategy evaluation. It is thought that the reason for this preference may be the pre-service teachers' past problem solving experiences. It is noteworthy that the pre-service teachers preferred a variety of activities related to the step of evaluating the solution of the problem and almost all of the lesson study groups preferred to use more than one activity in this step in their plans.

After the research lesson, some of the arrangements made by the pre-service teachers regarding the problem solving process were related to the addition of new instructions, rearrangement of the instruction statements or reordering the instructions in accordance with the steps of the problem solving process in order to make the instructions in the worksheets and lesson plans they designed for the problem solving process more understandable for the students.

It is thought that the collaborative structure of lesson study has a great role in ensuring the diversity of the activities carried out especially in the steps of understanding the problem and evaluating the solution (Doig & Groves, 2011; Stigler & Hiebret, 1999). In other words, problem solving-oriented lesson study practices offer richer learning environments through the collaboration of colleagues. In this context, it can be said that Lesson Study is a useful model for group work carried out in undergraduate programmes or for teachers' group work carried out in schools.

In addition, it is thought that the changes such as writing the instructions in the worksheets or lesson plans more understandable and easier, including a single question in each instruction and changing the location of the instruction are based on the fact that the pre-service teachers' knowledge of knowing the student is open to improvement and that the lesson study serves the pre-service teachers to complete these deficiencies thanks to the research lessons. From this point of view, it is thought that lesson study can be a functional tool in order to reinforce the theoretical knowledge offered by the problem solving courses in undergraduate programmes

with practice. In fact, it is suggested that in order for pre-service teachers to complete their existing deficiencies in the context of student recognition knowledge with problem solving-oriented lesson study practices to be carried out in the future, it is recommended to carry out lesson study practices in which mathematics teachers take part in the process as external experts. Kanbolat (2015) stated that such environments nourish teachers as well as pre-service teachers. Studies have shown that teachers approach skill-based problems uneasily, have partial difficulties in solving problems and need in-service training (Erden, 2020; Kertil et al., 2021). At this point, such practices, especially problem solving-oriented lesson study practices, are important in terms of providing exemplary learning environment designs for teachers who need support in the context of skill-based problems and problem solving process. Finally, in response to the question raised at the beginning of the study, it is thought that lesson study can be a functional tool in the process of incorporating skill-based problems into learning environments.

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