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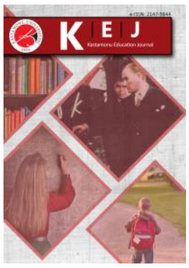

| Research Article / Araştırma Makalesi |

Pre-service Teachers' Knowledge of Statistical Questions in the Context of Lesson Study

Öğretmen Adaylarının Ders Araştırması Bağlamında İstatistiksel Sorulara İlişkin Bilgileri [1]

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Keywords

Pre-service teachers' knowledge
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Abstract

Purpose: This study aims to investigate the evolvement of pre-service teachers' (PTs') content and pedagogical content knowledge related to formulating statistical questions and its role in doing statistics through their participation in a lesson study.

Design/Methodology/Approach: A case study was employed, involving three PTs who participated in three lesson study sessions. Each group member implemented a lesson plan, initially in the university classroom and subsequently in a real classroom. The authors, the mentor teacher, and the group members observed the implementations and shared their insights. Data were collected through lesson plans, observations, and video recordings. The changes in PTs' knowledge were analyzed within the identified knowledge domains.

Findings: Initially the PTs did not have doing statistics starts with statistical questions, and these questions affect all phases of doing statistics. In task design, they omitted a problem statement guiding students to formulate a question and provided limited opportunities for students to contemplate problems leading to a statistical investigation. As the lesson study progressed, they began recognizing the significance of formulating a question. They became more attentive to students' prior knowledge and misconceptions.

Highlights: In the development of the PTs' knowledge and skills about formulating questions, some activities they conducted throughout the lesson study cycles are thought to be effective. Although they gained awareness about formulating questions in doing statistics, challenges persisted even in the last lesson study cycle. From this perspective, extended studies are necessary to elucidate the evolution of teacher knowledge.

Öz

Çalışmanın amacı: Bu çalışma, öğretmen adaylarının ders araştırmasına katılmaları boyunca istatistiksel soru formüle etme ve bunun istatistik yapmadaki rolü ile ilgili alan ve pedagojik alan bilgilerinin değişimini araştırmayı amaçlamaktadır.

Materyal ve Yöntem: Bu amaçla durum çalışması benimsenmiş, üç öğretmen adayı üç ders araştırması uygulaması gerçekleştirmiştir. Her grup üyesi, önce üniversite sınıfında ve ardından gerçek sınıfta hazırlanan ders planını uygulamıştır. Araştırmacılar, uygulama öğretmeni ve grup üyeleri uygulamaları gözlemlemişler, önerilerini dile getirmişlerdir. Veriler ders planları, gözlemler ve video kayıtları aracılığıyla toplanmıştır. Elde edilen veriler öğretmen adaylarının alan ve pedagojik alan bilgi bileşenlerindeki değişim bağlamında analiz edilmiştir.

Bulgular: Sürecin başında, öğretmen adaylarının istatistik yapma sürecinin soruları formüle etme ile başladığına ve bu aşamanın tüm süreci etkilediğine dair bilgiye sahip olmadıkları gözlenmiştir. Hazırladıkları görevler incelendiğinde, bu görevlerin öğrencileri -istatistiksel- soru formüle etmeye yönlendiren bir problem ifadesi içermediği ortaya çıkmıştır. Ayrıca öğrencilere istatistiksel araştırmaya götüren problem hakkında düşünmeleri için fazla fırsat vermemişlerdir. Ders araştırması uygulaması ilerledikçe öğretmen adayları neden bir soru formüle etmeleri gerektiğini anlamaya başlamışlar, öğrencilerin ön bilgilerine ve kavram yanılgılarına daha fazla dikkat etmişlerdir.

Önemli Vurgular: Öğretmen adaylarının soru oluşturma konusundaki bilgi ve becerilerinin gelişmesinde ders araştırma uygulamaları boyunca yaptıkları bazı aktivitelerin etkili olduğu düşünülmektedir.Öğretmen adayları istatistik yaparken soru formüle etme konusunda farkındalık kazanmalarına rağmen son ders çalışma döngüsünde bile çeşitli zorluklar yaşadıkları belirlenmiştir. Bu açıdan bakıldığında öğretmen bilgisinin gelişimini açıklamak için uzun soluklu çalışmalara ihtiyaç olduğu söylenebilir.

[1] This study is produced from PhD dissertation of first author conducted under the supervision of second author.

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INTRODUCTION

Statistics is a way to derive meaning from the real world by means of data (Wild, et al., 2018). Statistical research aims to solve problems that can be responded to by collecting and analyzing data (Graham, 2006). Doing statistics begins with formulating questions to solve a statistical problem and collecting data to find the answer to the question (Franklin et al., 2007; Scheaffer, 2006). Various tools, such as graphs and measures of central tendency and variation, are employed to organize and analyze the data (Franklin et al., 2007). In the last phase of doing statistics the results are interpreted based on the questions formulated at the beginning (Franklin et al., 2007). That is, the problem and the subsequent process of doing statistics directly in relation to each other (Bargagliotti, et al., 2020; Heaton & Mickelson, 2002). The questions formulated at the beginning shape the whole process of doing statistics (Arnold, 2013; Bargagliotti, et al., 2020; Franklin et al., 2007).

Emphasizing the significance of statistical research, it is crucial to recognize the vital role of the statistical problem in this process. Both teachers and students are encouraged to be 'critical consumers of data' in the teaching process, with teachers adopting the role of statisticians (Russell, 2006). In this process, teachers' both subject matter and pedagogical content knowledge about formulating questions play a critical role (Graham, 2006). However, challenges arise as teachers often find it difficult to support students' doing statistics during the teaching process (Arnold, 2013; Burgess, 2007; Heaton and Mickelson, 2002; Pfannkuch & Horring, 2005). Lesson study, which allows opportunities for teachers/PTs to develop their teaching, can be one of the important supporters (Lewis, 2002). By participating in lesson study, teachers can develop new knowledge, insights, and beliefs about student learning, ultimately improving their overall knowledge (Desimone, 2009; Ricks, 2011). This study examines how teachers' content and pedagogical content knowledge about formulating questions evolve during their involvement in lesson study.

THEORETICAL FRAMEWORK

In this section, formulating statistical questions in doing statistics in school mathematics, teacher knowledge, and lesson study are explained.

Formulating Statistical Questions in Doing Statistics in School Mathematics

Doing statistics is also emphasized in the school curriculum, and formulating the questions and understanding its role in this process are considered as important competencies that students should gain (Bargagliotti, et al., 2020; Franklin et al., 2007). In the Turkish context, doing statistics is included in the mathematics curriculum (Ministry of National Education [MoNE], 2018). It is essential for students to engage in doing statistics by formulating questions, collecting, analyzing, and interpreting data in a holistic manner (Burgess, 2011; MacGillivray & Pereira-Mendoza, 2011). However, doing statistics, and particularly formulating statistical questions in school, usually does not look like conducting statistical research in real life. The problems encountered in real life are usually ill-structured and ambiguous and make us feel needed to solve; there is a specific purpose for conducting a statistical inquiry (Graham, 2006; Pfannkuch & Horring, 2005). In contrast, questions formulated in the school curriculum are typically structured (Makar & Fielding-Wells, 2011). Researchers suggest that the statistical problems should be challenging and stimulate students' critical and creative thinking. Also, the statistical questions should allow students to collect data or think about how data could be collected. Importantly, the questions should lead to the collection of meaningful and logical data and be connected to daily life situations with clearly indicated group characteristics for data collection (Arnold, 2013; Graham, 2006; Franklin et al., 2007; Konold & Higgins, 2003; Pfannkuch & Horring, 2005; Russell, 2006).

Despite the emphasis on formulating questions, students often encounter difficulties in this process. Common challenges include an inability to determine if a given question is statistical, relying solely on personal beliefs during formulation, and overlooking the function of the question in doing statistics (Arnold, 2013; Heaton & Mickelson, 2002; Pfannkuch & Horring, 2005; Pfannkuch & Wild, 2004; Rubick, 2000). The content and pedagogical content knowledge possessed by teachers can play a crucial role in helping students overcome these challenges (Franklin et al., 2015).

Teacher Knowledge and Lesson Study

Effective teaching involves a comprehensive understanding of the mathematical subject being taught. Numerous studies emphasize that mathematics teachers should possess mastery across various knowledge domains (e.g., Hill et al., 2008). The foundation for defining the knowledge of teaching mathematics was laid by Shulman (1986), as articulated by Ball et al. (2008). This framework is essential for portraying middle school mathematics teachers' knowledge (Leavy, 2015). Within this framework, the knowledge of teaching mathematics is categorized into subject matter knowledge and pedagogical content knowledge. Subject matter knowledge is further divided into common, horizon, and specialized content knowledge. Pedagogical content knowledge is subdivided into content and students knowledge, content and teaching knowledge, and content and curriculum knowledge.

While common content knowledge includes knowledge that is not specific to the teaching environment, specialized content knowledge is determined as the knowledge that plays an active role in the teaching process and that a mathematics teacher should use in his/her professional life. Horizon content knowledge entails the awareness of the teacher about how the mathematics subject he/she focuses on is related to other subjects in the curriculum (Ball et al., 2008). One of the components of pedagogical content knowledge, knowledge of content and teaching is defined as the knowledge required to determine the appropriate teaching strategies and techniques, as well as the materials and demonstrations that the teacher will use in the teaching process, while knowledge of content and students is expressed as the knowledge of students' thinking styles, the difficulties they experience and the knowledge of being aware of mistakes and misconceptions. Knowledge of content and curriculum includes knowledge about the topics covered by the teacher, how the learning outcomes are addressed across the curriculum, and the order in which they are taught (Ball et al., 2008; Hill et al., 2008). It is thought that defining these types of knowledge as critical knowledge based on classroom teaching practices is also valid when teaching statistics, and that it is important to reveal this knowledge (Konold & Higgins, 2003).

The effectiveness of the teaching process related to statistics also depends on teachers' competence in content and pedagogical content knowledge regarding the doing statistics and the components in this process (Burgess; 2007; Franklin, et al., 2015). The first of these components is the formulation of questions (Bargagliotti, et al., 2020; Franklin et al., 2007; 2015). Research indicates that both teachers and PTs encounter difficulties in formulating questions. Although teachers acknowledge the significance of formulated questions, they struggle to teach this aspect of doing statistics (Burgess, 2007). Pfannkuch and Horring (2005) stated that teachers' ability to formulate questions was limited, while Heaton and Mickelson (2002) stated that PTs needed support in formulating questions. There is a need for studies exploring the importance and components of formulating questions and how they should be integrated into the teaching process for both teachers and PTs (Arnold, 2013). Shaughnessy (2007) emphasizes that existing studies on doing statistics primarily focus on data collection, analysis, and interpreting findings. There is a gap in understanding teachers' and PTs' perspectives on statistical questions and their role in teaching statistics.

To address these challenges, various supports, such as those proposed by Ball and Cohen (1999) and Ball et al. (2005), can aid PTs in overcoming difficulties. Lesson study is an impressive professional development program in terms of recognizing and eliminating the deficiencies of teachers (Chassels & Melville, 2009; Saito et al., 2006). It includes constructivist learning and creates learning opportunities (Dudley, 2014). While rooted in in-service teacher training, lesson study is successfully applied in PT training (Fernandez & Zilliox, 2011; Leavy, 2015; Sims & Walsh, 2009). It involves collaborative planning, implementing, and analyzing lessons to enhance teaching effectiveness. PTs' participation allows for eliciting their content and pedagogical content knowledge, facilitating connections between these knowledge types (Leavy, 2015). Considering the impact of teachers' knowledge and skills on student achievement (Desimone, 2009), supporting the development of this knowledge becomes essential. Given that the practices, knowledge, and beliefs of PTs are significantly shaped during pre-service education programs (Kyles & Olafson, 2008), examining PTs' knowledge is crucial. Analyzing their own teaching, a practice with a long but less noticed history (Hiebert et al., 2007), is argued to provide learning gains for PTs (Van Es & Sherin, 2002). It can be thought that the practices carried out during the lesson study will be an important supporter at the point of imparting these skills to PTs (Ball & Cohen, 1999).

The process of doing statistics and revealing the deficiencies in teachers' knowledge about formulating questions in this process (Arnold, 2013; Heaton & Mickelson, 2002; Pfannkuch & Horring, 2005) requires teachers to acquire content and pedagogical content knowledge about the properties of formulating questions and to understand how it will reflect in the classroom environment (Arnold & Pfannkuch, 2018). Lesson study can play a crucial role in supporting the development of teachers' knowledge in this regard (Knapp et al., 2011).

METHOD/MATERIALS

The qualitative research method was employed, and a case study was adopted to thoroughly investigate changes in the knowledge and experiences of prospective teachers (PTs) during their participation in lesson study cycles. The aim was to understand these changes in greater detail within the natural course of their involvement, discern their implications, and learn about their perspectives.

Context of the Study and Participants

The context of the current study is a four-year elementary mathematics teaching program at a state university in Ankara. When they have graduated from this program, teachers can teach mathematics to 5th-8th graders. The language of instruction in the program is Turkish. PTs mostly receive subject matter courses for the first two years (e.g., Fundamentals of Mathematics), and then in the last two years, they mostly receive pedagogical content knowledge courses (e.g., Methods of Teaching Mathematics, Teaching Practicum). In this context, the elective course was opened. The selection of participants was based on criteria such as voluntary participation and successful completion of courses related to statistics teaching (e.g., Statistics and Probability). Twelve PTs meeting these criteria opted for the elective course. The study included data from Beyza, Şirin, and Gamze, who played more active roles in the observations and discussions throughout the process and expressed themselves effectively. The GPAs of the PTs were as follows: Beyza 3.21, Şirin 3.26, and Gamze 3.29 out of 4, respectively.

Procedure

This study lasted for 14 weeks. During the initial three weeks, participants were introduced to the course, reading and discussing articles on the field of data analysis (Ben-Zvi, 2011; Cobb & McClain, 2004). In the ongoing week, information was given about the lesson study model and how the process would proceed was discussed. In the next three weeks, pre-pilot study was conducted. The first aim of this pilot study was to get to know the PTs more closely and to make them gain experience in the lesson study process. The second aim was to ensure that both students in the real classroom environment and the PTs get used to each other. In the next seven weeks, PTs implemented lesson study. The process is illustrated in Figure 1.

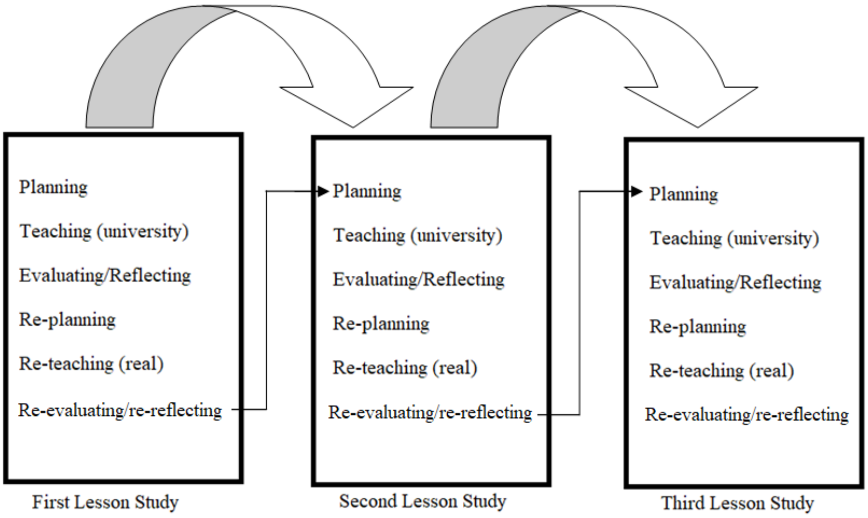

Figure 1. Lesson study cycles (Adapted from Zhang & Cheng, 2011)

The PTs focused on three objectives related to the data handling learning area (MoNE, 2018) and conducted the lesson study cycles. The PTs were asked to prepare their lesson plans according to the lesson planning format (learning activities, expected student responses, teacher's responses, goals, and methods of evaluation) (Mathews et al., 2009). Following the completion of the lesson plans, one PT from each group implemented the lesson initially in the university classroom and then in the real classroom. Each group member was responsible for implementing one of the three designed lesson plans. During the implementations, the course instructor (second author) and the researcher (first author), serving as an expert in the university, observed and provided feedback. Additionally, PTs and group members shared their comments and recommendations on how to enhance each lesson plan. In the real classroom, the mentor teacher and the researcher (first author) attended each implementation as observers, offering comments and suggestions.

Data Collection and Analysis

Data were collected from various sources to comprehensively analyze the discussed situation (Creswell et al., 2007). The following data collection tools were employed in this regard: lesson study meetings, video recordings of both university and real classroom implementations, lesson plans prepared by PTs, observation notes, field notes taken by the researcher, and reflective papers written by the PTs. Table 1 illustrates the relationships between the lesson study cycles and the employed data collection tools.

Table 1. Data collection tools used across the lesson study cycles

Data Collection Tools	Planning	Teaching (university)	Evaluating/Reflecting	Re-planning	Re-teaching (real)	Re-evaluating/ Re-reflecting
Lesson plans	x			x		
Video recordings of the lesson planning meetings	x			x		
Researcher's field notes	x	x	x	x	x	x
Video recordings of the lessons delivered		x			x	
Expert's observation notes		x			x	
Observation notes of the other PTs in the group		x			x	
PTs' reflective papers			x			x
Video recordings of the evaluation meetings			x			x

In the process of analyzing data, statistical questions proposed by the PTs were coded based on various characteristics of statistical questions as identified in the literature (Arnold, 2013; Arnold & Franklin, 2021; Franklin et al., 2007; Graham, 2006;

Konold & Higgins, 2003; Makar & Fielding-Wells, 2011; Pfannkuch & Horring, 2005; Russell, 2006). It was not analyzed in terms of the components of the subject matter knowledge (e.g., specialized content knowledge), but rather analyzed holistically because the existing research indicates that there is no need to evaluate the components of the subject matter knowledge separately from each other and that it is important to see the holistic picture (Putnam & Borko, 2000). The emergence of each type of knowledge in the lesson study processes was observed and evaluated using direct quotations where necessary.

Table 2. Teacher knowledge domains, sub-domains and definitions in the analysis process (Developed by Ball et al., 2008)

<table>
<tr><th>Knowledge domains</th><th>Knowledge subdomains</th><th>Definitions</th></tr>
<tr><td>Content knowledge</td><td></td><td>Knowing that the doing statistics starts with formulating a question
Knowing what the properties of formulating questions are,
It involves a problem situation or a purpose that encourages students to initiate a statistical investigation,
It is related to contexts involving real-life situations;
It allows data collection or thinking about the data collection process;
The group characteristics for which data will be collected are clearly indicated.</td></tr>
<tr><td rowspan="2">Pedagogical content knowledge</td><td>Content and teaching</td><td>Making explanations around formulating questions
Constructing the tasks they have prepared around formulating questions
Making explanations to make students realize that the problem-solving process starts with formulating questions and motivating them to such explanations</td></tr>
<tr><td>Content and student</td><td>Taking students' prior knowledge into account (e.g., a bar chart is a prerequisite for a pie chart)
Taking the points where students can have difficulties into consideration (e.g., overlooking formulating questions,)
Taking potential thoughts of students into consideration (e.g., the same data are represented with both a bar chart and a pie chart.)</td></tr>
</table>

The analysis was conducted for each lesson study cycle. The researcher coded the raw data in different time periods (three months). The consistency obtained from these encodings was 90%. Also, an expert in mathematics education was asked to review the data. Twenty-five percent of the data was provided to the expert, and the emerging codes were compared with those obtained by the researcher. The intercoder reliability of the study was determined to be 85%.

FINDINGS

How the PTs' content, teaching and student knowledge regarding the formulating questions changed during their participation in the lesson study cycles was discussed in each lesson study.

First Lesson Study

The PTs were observed to neglect the inclusion of statistical questions in both their task design and lesson implementation for the first objective (pie graph-7th grade). It was noticed that the questions they formulated focused solely on data and real-life situations, lacking a statistical aspect. However, the PTs began recognizing the importance of formulating questions in doing statistics when reading about it in the course textbook section: *"As you evaluate students in the area of graphing, it is important not to focus undue attention on the skills of constructing a graph. It is more important to think about the choice of graphs that the students make to help answer their questions or complete their projects. Your goal is for students to understand that a graph helps answer a question and provides a picture of the data."* (Van de Walle et al., 2010, p. 445) (1. University Planning). They, however, did not take into account this phase of doing statistics in their planning of the lesson related to the first objective they worked on. Moreover, they did not connect it with the data collection process, although group characteristics were included. Their task required students to convert a bar graph into a pie graph without presenting a problem or reason that leads to formulating a question. In the written lesson plan they noted *"Let's convert bar graphs into circle graphs". Gamze, who was carrying out the lesson expressed their expectation "…Now we have bars of different lengths, right? Now, if we thought of them as sticks, how could you turn them into a pie or a circle? How can you convert?*" (1. University Planning). Despite attempts to consider students' prior knowledge, such as a bar graph being a prerequisite for a pie graph, they failed to address typical thoughts and points of difficulty. At the end of the implementation the instructor of the course asked *"…Why do we construct a pie graph? We need to think about it…"*and reminded them that they should have a purpose in doing statistics. In their reflection, Şirin stated that *"…The purpose of statistics was to answer a research question [formulating questions], I couldn't understand it before."* while Beyza stated that *"I have learned what to use when creating a research question [formulating questions] and in which situations we should ask which questions"*. Therefore, it can be said that PTs realized the importance of formulating questions in doing statistics with the first implementation. Thus, it can be concluded that their content knowledge started to improve. However, they have had difficulty in reflecting this understanding on their revised lesson plan and the teaching in the real classroom. Gamze introduced the task without any problem situation that led to formulating a question for students: *"Well, I want to ask you something. Now, isn't this* *data from the bar graph? I want to convert it to the shape that you call as a pie but actually a circle graph."* Even though formulating questions did not take part of their instruction, these experiences helped them to ask questions about the purposes of doing statistics and increased their awareness as shown in Şirin's reflection: *"As a group, we were focusing only on constructing graph while preparing lesson plans. In fact, the main thing in graphing is the research question [formulating questions]. We were always skipping this part. Thanks to this lecture, we realized this situation."*

Second Lesson Study

Concerning the second objective (line graph-7th grade), a similar trend was observed in the planning and implementation of the lesson in the university classroom. During this session, Şirin, who conducted the lesson, presented the task to students by stating, *"...Let's say I presented the average weather temperature of a city for 5 days. I want you to display this [data set] into a graph. What kind of a graph do I use?"* (2. University Teaching). However, it was noted that the PTs still did not incorporate any problem situation or purpose that led to formulating a question. At the end of the teaching, the instructor once again pointed out that there needs to be a purpose in lesson plans *"For what purpose do we use statistics? What's the point? Why are we comparing [the temperatures] here?"* (2. University Evaluating). Through these experiences, the PTs became more attentive to formulating questions as they revised the tasks. At this juncture, it can be argued that there have been some improvements in their pedagogical content knowledge. During the re-planning meetings, they specifically focused on creating the problem statement.

Second lesson study re-planning

"..........

Şirin: Then I introduce the problem situation… Uncle Hasan will plant a vegetable. Let us present one condition for planting this specific vegetable: There should be the lowest change in the temperature for two consecutive days after the seeds are planted. At least this many days there should be little change in temperature. There must be almost none.

Beyza: Should we specify that the temperature should remain constant, or do we express it as minimal change?

Şirin: We'll say that there will be a change; the temperature cannot stay constant for 3 days.

Beyza: Well, there is little change. It is very important that the temperature does not change much.

Şirin: For example, we will present [temperature values] for two weeks. It will increase and decrease. But we will ask them to find the days with little change [of temperature]. ....

Şirin: I asked how we could have collected the data. Now we have presented a problem situation. This is our problem situation; the aim is to solve it. The aim is to solve this problem. Let's go with proper graphic construction. Then let's guide it a little…"

It was observed that PTs talked about presenting a problem situation and a purpose. In addition to including real-life situations, they clearly stated group characteristics. Moreover, the prepared formulation question requires data collection.

"Uncle Hasan will plant a vegetable in his garden. In order to get the highest yield from this vegetable, the temperature change should be the least for 2 days after the day it is planted. We've got the temperature values for the next 14 days.

1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*
20°C	*23°C*	*25°C*	*22°C*	*19°C*	*23°C*	*26°C*	*24°C*	*25°C*	*26°C*	*25°C*	*23°C*	*20°C*	*24°C*

Let's find the best days of planting for Uncle Hasan."

Figure 2. Revised task

It was observed that the revised task involves a problem situation (i.e., we can't plant the seeds on a random day if we want the highest yield) and a purpose (i.e., finding the best day to plant) that leads to formulating a question (which consecutive days the temperature change will be the lowest) that requires dealing with data. During the implementation Şirin introduced the task and asked students if they could use a bar graph. An excerpt from the class discussion is as follows.

Second Real Classroom Teaching

"...

Şirin: So, what graphics did we learn?

Student: Bar graph, circle graph, pie chart, sector, tally table.

Şirin: Yes, now we have learned these graphs. So, what was the bar graph? Let's construct a bar graph. Let's see if this is a graph suitable for the data or what I'm researching...

The PT's following statement uttered during the implementation *"Let's see if this is a graph suitable for the data or what I'm researching,"* shows that he/she not only tried to make students think but also to establish a relationship between the data analysis process and the initial research purpose/problem. Additionally, Şirin's question aimed to assess prior knowledge and encourage students to think about the problem, leading them to formulate questions.

Second Real Classroom Teaching

"..........

Şirin: What was our question then? What was our initial problem?

Student: Uncle Hasan is going to plant a vegetable. But the temperatures should be close to each other for crops.

Şirin: Exactly, we will choose days without much change. We'll choose three days and there won't be much temperature change. Then let those who finish the graph find these days.

Student: We found it.

....

Student: 9., 10., and 11. (days), my teacher.

Şirin: Now what was our question? In order to plant the vegetable at the right time, the temperature change must be the lowest. Yes, 9th, 10th, and 11th days; then we solved this question…"

In the dialogue above, it is seen that the PT used the question and problem together by asking *"What was our question then? What was our initial problem?"* Here, it can be said that though their awareness of the fact that the research question includes a problem increased, they still tend to use them interchangeably. However, Şirin effectively guided students to consider the problem and stated in her journal, *"We understood the importance of graph interpretation in a lesson plan for teaching line graph according to a research question [formulating questions] based on the problem situation."* Even though the PTs have realized the importance of formulating questions in doing statistics, they were still struggling with designing tasks that involve a problem situation and a question to be addressed by engaging with data meaningfully.

Third Lesson Study

When planning a lesson for the third objective (pie, line and bar graph-7th grade), PTs avoided using statements directing students to construct a specific type of graph. Instead, they designed tasks with certain properties in mind: tasks that involved real-life situations, clearly presented group characteristics, and directed students toward data collection. They aimed to structure the tasks so that students decide which type of graph to use by themselves. They, however, overlooked presenting a problem situation that could lead students to formulate questions and proceed accordingly. Rather, they focused on presenting keywords (e.g., compare, change, ratios, or percentages) that could be associated with certain types of graphs or used general statements (e.g., use appropriate graphs) without presenting a rationale to use the specific type of graph. The following dialogue illustrates their attempt to formulate a question when designing a task related to pie graphs.

Third University Planning

"…..

Beyza: Let's give them data like yours [referring to Gamze's suggestion] and ask them to represent the data with the appropriate graph type.

Gamze: Then we can ask, "Which graph do we need to use to show the proportion of the part of the wage paid for the rent to the whole wage?

Şirin: For example, …when there is temperature data, they think a line graph is more appropriate. For the circle graph, as Gamze said, in the question part, we [should?] state that they can proportion to the whole. What can we say for the bar graph? We directly say, construct a graph. Or comparison of age groups with each other.

....

Gamze: In fact, all the graph types can be used. Thus, the question that needs to be asked is "Which graph is more suitable? For example, they are planning to construct a graph in order to see the ratio of the rent to the whole salary more easily. Which graph would be more convenient to use?"

While PTs occasionally provide examples illustrating the purpose of formulating questions during discussions (e.g., determining the ratio of rent to the entire salary), they struggle to incorporate a problem situation and purpose when formulating questions for implementation. It is evident that PTs tend to focus on keywords. The main reason for using the keywords was to reveal the purpose of selecting the particular type of graph. However, in a learning environment that encourages doing statistics, students are expected to form the purpose from the problem situation themselves. Without the problem statement, attempting to create a match between the keyword and the graph type may prevent deriving meaning from situations requiring the use of data. Although the PTs occasionally considered whether the task included a problem situation, they usually did not consider it as an issue. As exemplified in the task below (Figure 3), the question formulated by the PTs lacks a problem situation. Although the task includes statements such as "construct the appropriate graph," "interpret the relative position of three courses within the whole data," and "find the percentages," there was no problem situation expressing why the relative position of three courses within the whole data set should be considered.

"Favorite courses in class 7/A

Courses	*Number of students*
Mathematics	*4*
Turkish	*3*
English	*2*
Physics Education	*5*
Art	*1*
Science	*3*
Social Studies	*2*

The table shows the number of the students in class 7/A and their favorite courses. Construct *the appropriate graph according to this data and interpret the ratio of the 3 courses you selected according to the whole class and find the percentages."*

Figure 3. University Lesson Plan-Circle Graph

Similar situations were noted in the preparation of tasks involving bar and line graphs. These instances reveal that participants (PTs) tended to place keywords at the center when formulating questions. The fact that PTs formulated questions by focusing on keywords caused them to make their explanations and feedback accordingly during classroom implementation. The following excerpt illustrates a segment of the decision-making process related to the circle graph in a university classroom.

Third University Teaching

"...

Beyza: Okay, how do we do this?

Student: Well, when it says percentage, I directly think of a circle graph.

Beyza: Is it just because of the percentage?

Student: Yes, percentage. I also thought that the circle graph would be appropriate for us to look at the data and find the rates compared to the whole.

In the dialogue mentioned earlier, both the PT and the student primarily concentrated on the keywords. After the teaching, PTs evaluated themselves and decided to make some revisions to the task. In the revised task, they included a purpose as a rationale for constructing a particular graph:

The table shows the number of the students in class 7/A and their favorite courses. The teacher wants to know whether mathematics is popular among all courses. Construct the appropriate graph and interpret the relative position of mathematics among two other courses that students state as favorite.

Figure 4. Revised Task-Circle Graph

In fact, the reflection journals of the PTs also revealed their recognition of the importance of introducing a problem situation or purpose. For instance, Beyza highlighted, *"I have learned that I must present students with a problem situation so that they have a purpose and can act accordingly."* Similarly, Şirin articulated, *"The students' need to use a graph is crucial. Consequently, we must design the problem situation in a way that necessitates the use of a bar graph; we came to this realization."*

The PTs also started to consider students' thinking as they design the tasks and formulate the questions. For instance, they decided to create a task related to voting that prompts a comparison among categories, necessitating the use of a bar graph. Recognizing that data related to voting are typically represented by pie graphs, PTs chose to construct students' attention to the formulated questions rather than solely focusing on keywords or familiar contexts. Furthermore, PTs initiated opportunities for students to generate their own questions. They emphasized that determining the most suitable type of data representation depends on the questions formulated. Their commitment to making students aware of the role formulated questions play in selecting the type of data representation is evident in Beyza's classroom teaching.

Third Real Classroom Teaching

"....

Beyza: …Now, let me pose a question. In this scenario, can we assert that either the bar chart or the pie chart must be employed? Consider this: for the first statistical question we discussed, we used the pie chart; for the second question, we used the line chart, and for the third question, we used the bar chart. Couldn't we have used the pie chart in the situation where we opted for the bar chart?

Student: Yes, we could

Beyza: Why didn't we construct it then?

Student: The question asked us to choose the president and vice president. Since we can see it as a percentage, we will calculate votes. According to whichever person has the most votes. To find whoever has the most votes.

Beyza: Yes, it says the most, we are comparing with each other. That is, there is no certain discrimination between the uses of different types of graphs. I use the one that is the most suitable for answering the statistical question. So, what matters here is what it wants from me. What I should see with my graph. So, whatever I should see on the graph, I choose my graph accordingly.

Here Beyza's efforts to attract students' attention to the questions formulated while deciding the most appropriate type of graph.

DISCUSSION, CONCLUSION AND SUGGESTIONS

This study aimed to explore the PTs' knowledge and skills related to formulating questions that can be addressed by collecting and analyzing data when doing statistics in a lesson study. Initially the PTs did not have the idea that doing statistics starts with formulating questions and that these questions affect all aspects of doing statistics. This lack of understanding has been reflected in their lesson plans and implementations. When designing tasks, they did not include a problem statement that could lead students to formulate a question to be addressed by constructing a graph. They simply asked students to construct a graph or convert one type of graph into another without presenting a rationale. This practice risks students perceiving graphs as mere tools for data organization, summarization, and simplification, rather than as tools for addressing statistical questions (Rouan, 2002), aligning with earlier research (Heaton & Mickelson, 2002; Pfannkuch & Horring, 2005). Even experienced teachers turned out to be structuring their lessons by centering statistical calculations (Quintas et al., 2014). Early experiences in school that did not consider all the stages of doing statistics may have been an important factor in PTs' incompetence (Arı, 2010).

Even as PTs gained knowledge and awareness of the need for problem statements, integrating this into classroom practice proved time-consuming. When designing tasks, they began to avoid merely asking to construct a particular type of graph or convert a graph into another. While the tasks they prepared had a purpose, they often did not include a problem situation that would direct students to formulate a statistical question. They either presented general statements (e.g., let's display given data with an appropriate graph) or they used keywords (e.g., compare, change) that could guide students to use a particular type of graph without stating a problem situation.

As the PTs endeavored to generate problem situations, they became more discerning in context selection. The problem situation and purpose that directs individuals to conduct statistical research gain meaning within the context. Therefore, the selection of context plays a pivotal role in effective statistics teaching (Franklin et al., 2007; Monteiro & Ainley, 2007). Guided by an expert teacher, they sought to capture students' attention by presenting a variety of contexts. Initially, PTs selecting a context for a problem situation involved discussing real-life scenarios typically associated with a specific graph type (e.g., depicting temperature changes with a line graph). However, the PTs began questioning the use of such prototypical situations and their associations with specific graph types, recognizing the potential for student overgeneralizations. Subsequently, they considered common conceptions, such as using pie graphs to represent votes, and designed a task with a context involving votes where a bar graph would be more appropriate. This case demonstrates their growing awareness of students' thinking and misconceptions.

The PTs also began recognizing how the questions formulated at the beginning influenced the stage of data collection and analysis. Initially, they considered only the type of variable (categorical or quantitative) when deciding which graph would be more appropriate to represent a data set. In the discussions made during the university implementation, PTs stated that they came across such generalizations in various textbooks, and therefore, they felt that these statements were true. Similar difficulties were identified in the literature (Burgess, 2002; Sorto, 2004). For example, in Sorto's (2004) study, the PTs expressed that a variable such as time should be represented by a line graph rather than a bar graph. It was revealed that they always thought that the time variable should be quantitative, so it would not be appropriate to represent the time variable with a bar graph. In the present study, as PTs faced queries from students regarding the possibility of representing data with alternative graph types, they began questioning common assumptions that categorical variables should be portrayed with a circle or bar graph, while quantitative variables should be depicted with a line graph or histogram. They realized that determining the variable type should be based on the formulated question, emphasizing the importance of considering the initial question when deciding which type of graph would be more appropriate to use.

We also noticed an improvement in the PTs' ability to engage students in the lesson. Initially, PTs didn't provide students with many opportunities to contemplate the problem; they typically presented the problem statement and formulated questions themselves. As they gained more experience, they began to think about the ways to include students in doing statistics. They provided more opportunities for students to think about the problem statements. However, there were missed opportunities for PTs to guide students in formulating questions from the presented problems. Additionally, they endeavored to formulate questions anticipating potential student misconceptions. They emphasized the role of graphs in responding to a statistical problem and made inquiries that would enable students to think in this direction. Alongside considering students' prior knowledge, they reflected on potential difficulties, mistakes, and misconceptions students might encounter.

In the enhancement of PTs' knowledge and skills in formulating questions, some activities conducted during lesson study practices are deemed effective. One of the main points highlighted in the research is to design classroom activities with a focus on doing statistics (Garfield & Everson, 2009; Heaton & Mickelson, 2002; Henriques & Ponte, 2014). At the beginning of this study, all stages of doing statistics were discussed with the PTs. However, it can be said that these discussions were not very effective until the PTs began teaching practices. They became aware of the doing statistics as they practiced, talked about, and experienced. Discussions with each other as a group and the discussions after teaching both in the university and in the real classroom can be considered as an important factor that triggers the change. The questions posed by the instructor (university classroom) and the mentor teacher (real classroom) played a pivotal role in helping PTs identify knowledge gaps and recognize the need for improvement. Such experiences potentially fostered knowledge sharing and diverse perspectives among PTs (Hiebert et al., 2003).

This study reaffirms the critical importance of PTs graduating with substantial field experience. In this regard, it can be suggested to open courses that will allow PTs to practice in real classroom. Existing research emphasizes that the planning, implementation, and evaluation activities of PTs in both university and real classrooms contribute to their knowledge development (Zhang & Cheng, 2011). The presence of a researcher who facilitates the change of PTs' knowledge throughout the process could be considered as another factor that may have trigged such development. The researcher actively participated in and supported PTs in all processes. In both planning and revising meetings, the researcher supported the change of knowledge by asking PTs questions to make detailed explanations of what they did and how they did and help them reflect on their own understandings and skills. Existing literature underscores the researcher's crucial role in recognizing and interpreting deficiencies in teachers' knowledge and overcoming these gaps (Ball & Cohen, 1999; Zawojewski et al., 2008). In light of the findings from this study, it can be argued that PTs conducting implementations focusing on formulating questions in statistics and understanding the features included in the questions contributed significantly to the development of their pedagogical content knowledge.

While the previously mentioned changes were evident in the knowledge of PTs, their capacity to develop tasks that support students' statistical thinking remains incomplete. These findings support that change in teacher knowledge and skills is a long and time-consuming process (Fullan, 1991). It can also be said that although different data collection tools were used to reveal and observe the PTs' knowledge and skills in this study, it was not easy to make inferences about their development. For instance, although changes in subject matter knowledge were observed and reflected in their practice, these changes were not consistently observed in subsequent implementations. Though they gained awareness about formulating questions in doing statistics, they experienced difficulties even in the last lesson study cycle. Hence, it becomes evident that long-term studies are essential to comprehensively elucidate the evolution of teacher knowledge.

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We hereby declare that the study has not unethical issues and that research and publication ethics have been observed carefully.

Author contribution statements

This study was a part of PhD dissertation of first author conducted under the supervision of second author.

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This study was conducted and reported with equal collaboration of the researchers.

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