Examining the Change of Pre-Service Middle School Mathematics Teachers' Questioning Approaches Through Clinical Interviews

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Received: 19 August 2019 Accepted: 10 August 2020

Questioning is a core practice used comprehensively in many areas of teaching mathematics. It is an important part of the teacher's ability to establish a classroom atmosphere conducive to the development of mathematical thinking. The study aimed to investigate the types of questions used by pre-service middle school mathematics teachers (PSMTs) and the change of PSMTs' questioning approaches while conducting clinical interviews with students over the course of a semester. The study was implemented during an undergraduate course offered for PSMTs at a public university in Turkey in the spring semester of the 2017-2018 academic year. The participants consisted of 22 PSMTs who worked in nine groups of two to three. The PSMTs conducted interviews with middle school students from Grades 6, 7 or 8 three times over the length of the course. The data sources were the transcriptions of the audiotaped interviews conducted by PSMTs. The findings showed that the PSMTs used six different types of questions over three interviews ranging from yes-no questions to probing questions, but that four groups of PSMTs did not change their questioning approaches from the first interview to the third interview. Conducting clinical interviews around mathematical tasks may be a valuable activity for PSMTs in terms of practicing questioning and developing their questioning approaches towards probing student thinking. Therefore, this study has implications for mathematics teacher educators concerning use of this method in PSMTs' training for changing PSMTs' questioning approaches.

Keywords Clinical interviews · pre-service middle school mathematics teachers · questioning · student thinking

Introduction

A number of studies (e.g., Ball & Cohen, 1999; Fennema, Carpenter, Franke, Levi, Jacobs, & Empson, 1996) emphasize the importance of teachers' eliciting and attending to students' mathematical learning and thinking. The NCTM [National Council of Teachers of Mathematics] (2014) pointed out the importance of using evidence of student thinking as follows: "Effective teaching of mathematics uses evidence of student thinking to assess progress toward mathematical understanding and to adjust instruction continually in ways that support and extend learning" (p. 3). While understanding students' mathematics learning and thinking is central to effective teaching, this understanding does not develop automatically. The development of such understanding needs to be part of both pre-service teacher education courses and professional development programs for teachers (Even & Tirosh, 2002). In recent

years, a growing body of research on teacher practice focusing on the pre-service and in-service teachers' noticing, understanding and interpreting of students' ways of thinking suggests various practice-based interventions including investigating teaching and learning artefacts, assessing and analysing misconceptions in students' homework, and viewing video clips of students or conducting interviews with students (e.g., An & Wu, 2012; Jenkins, 2010; Stockero, Rupnow, & Pascoe, 2017). Among these interventions, the clinical interview is regarded as one of the most powerful ways for teachers to elicit and explore students' thinking, practice questioning techniques, and assess students' learning and development (Dunphy, 2010; Heng & Sudarshan, 2013; McDonough, Clarke, & Clarke, 2002). Interviewing students provides teachers with opportunities to practice eliciting and building on students' thinking by engaging them in discussing problems and helps them to develop the expertise to respond to that thinking (Ambrose et al., 2004). Interviewing students also provides teachers with opportunities to practice questioning techniques and to learn to ask questions that are more effective in eliciting students' mathematical thinking (Groth et al., 2016; Heng & Sudarshan, 2013; Jenkins, 2010; Moyer & Milewicz, 2002). As real experiences, conducting interviews with a student could offer valuable learning contexts to support teachers' and pre-service teachers' questioning skills (Moyer & Milewicz, 2002).

Questioning is a core practice in the instructional process (Moyer & Milewicz, 2002), and asking appropriate questions is considered one of the most important skills of any teacher (Harrop & Swinson, 2003). Burns (1985) said that, "Questioning is an important part of the teacher's ability to establish a classroom atmosphere conducive to the development of mathematical thinking" (p. 16). In documenting the importance of teachers' questions, many researchers have focused on teachers' questioning practice and the types of questions used by teachers in classrooms (e.g., Boaler & Brodie, 2004; Franke et al., 2009; Gaspard & Gainsburg, 2019; Latham, 1997; Martino & Maher, 1999; McCarthy, Sithole, McCarthy, Cho, & Gyan, 2016; Paoletti, Krupnik, Papadopoulos, Olsen, Fukawa-Connely, & Weber, 2018). Teachers predominantly use closed and low-level cognitive questions rather than higher-order cognitive questions (e.g., Boaler & Brodie, 2004; Brualdi, 1998; Günay-Bilaloğlu, Aktaş-Arnas, & Yaşar, 2017; Sahin & Kulm, 2004). For this reason, recognising, learning and practicing various types of questions should be part of all teacher education programs and improving pre-service teachers' questioning skills should be an integral focus of mathematics education courses (Moyer & Milewicz, 2002).

Although some studies have documented pre-service mathematics teachers' questioning skills or categorised the types of questions used by pre-service mathematics teachers within the context of conducting interviews (e.g., Groth et al., 2016; Moyer & Milewicz, 2002), fewer studies have focused on the change and the development of their questioning skills as they performed interviews to elicit student's thinking (e.g., Weiland et al., 2014). Because conducting interviews was proposed as one of the strategies that can help pre-service mathematics teachers to learn about both students' thinking, and develop their questioning techniques, in this study we provided opportunities for pre-service middle school mathematics teachers (PSMTs) to conduct clinical interviews with students three times during a semester. We aimed to investigate the types of questions used by PSMTs and the change of PSMTs' questioning approaches during their clinical interview experiences. The following research questions guided this study.

1. What were the types of questions used by PSMTs while conducting clinical interviews with students over the course of a semester?
2. In what ways did the PSMTs' questioning approaches change while conducting clinical interviews with students over the course of a semester?

Clinical Interviews in Teacher Development

The clinical interview is a flexible and deliberately non-standardised method of questioning (Schorr, 2001). The aim is to seek understanding of a child's underlying thought processes through flexible questioning to elicit the best responses from the child (Heng & Sudarshan, 2013). Heng and Sudarshan (2013) found that clinical, task-based interviews opened a window into students' knowledge, problem-solving methods, and reasoning, and helped teachers reflect on their teaching and assessments of student learning. They highlighted that understanding their students' thinking helped teachers improve in their teaching. They also indicated that the teachers learned about thoughtful questioning and creating a questioning culture in the mathematics classroom by conducting interviews. Jenkins (2010) found that structured clinical interviews helped pre-service teachers gain an interpretive orientation to listening and gain an initial awareness of the variety of ways in which middle school students think about mathematics. Haydar (2017) found that using clinical interviews improved teachers' questioning skills, helped them ask more questions that shaped understanding or pressed for reflection, and brought the voices of their students back into lesson planning and the teaching of early algebra mathematics lessons.

Questioning

Mason (2014) argued that questions and other prompts are useful in assisting students to "get unstuck or to direct their attention in a potentially useful way so that they make mathematical progress" (p. 514). Questioning is used comprehensively in all areas of teaching as an assessment strategy with which to identify students' knowledge, understanding, feelings, and needs. Further, it is used as a strategy to control students' behavior and maintain their attention as well as to induce and direct students' thinking processes and challenge their ideas (Newton, 2001). Teachers' questions can shape the nature of the classroom environment, support students in being more explicit in their explanations, teach students to ask crucial questions concerning their own work, offer cognitive opportunities to promote students' learning, scaffold students' engagement with the tasks, and help the teachers themselves understand student thinking (Boaler & Brodie, 2004; Franke et al., 2009; Latham, 1997; Moyer & Milewicz, 2002).

Different types of teachers' questions, such as high-level questions and low-level questions (e.g., Brualdi, 1998; Cotton, 1989); factual questions (e.g., Hiebert & Wearne, 1993; Sahin & Kulm, 2008; Vacc, 1993); probing questions; leading, guiding or orienting questions (e.g., Franke et al., 2009; Paoletti et al., 2018; Sahin & Kulm, 2008), have been reported in the research. Whereas the act of asking a good question is cognitively demanding, no single questioning technique works best in every situation. Teachers should have a broad repertoire of techniques to use in the changing classroom environment (Latham, 1997). Furthermore, it is important for the teachers to use the appropriate question types in a given situation that supports the type of learning that is involved; therefore, the teacher should employ both low-level and high-level questions. On the other hand, the inappropriate use or over-use of low-level questions, which are referred to as fact, closed, direct, recall, and knowledge questions (Cotton, 1989), can limit students' learning since they typically do not help students acquire a deep and robust understanding of the subject matter (Brualdi, 1998). The use of more high-level questions, which are open-ended, interpretive, evaluative, inquiry, and inferential in nature (Cotton, 1989), can contribute to students' construction of more sophisticated mathematical knowledge. Latham (1997) highlighted that instead of asking a question with a single right answer, asking "Why" questions developed students' abilities. For example, probing questions, as high-level questions, require students to

explain and elaborate on their thinking (Boaler & Brodie, 2004; Paoletti et al., 2018). As probing questions extend students' knowledge beyond factual recall and push students to think more deeply, they help to maintain the focus on students' thinking (Sahin & Kulm, 2008). Franke et al. (2009) indicated that a teacher's use of a probing sequence of specific questions enabled them to understand the details of students' mathematical thinking fully. In summary, the use of probing questions guides classroom instruction (Franke et al., 2009; Moyer & Milewicz, 2002) and contributes to students' constructions of more sophisticated knowledge (Martino & Maher, 1999). Therefore, developing pre-service mathematics teachers' questioning skills in terms of probing student thinking is essential (Moyer & Milewicz, 2002; Weiland et al., 2014).

Method

A qualitative case study was used to investigate the types of questions used by PSMTs and the change of PSMTs' questioning approaches while conducting clinical interviews with students over the course of a semester.

The Research Context

This study was conducted during an undergraduate course offered for PSMTs at a public university located in a city in Turkey during the spring semester of the 2017-2018 academic year. The course was a lecture-based course and designed to give PSMTs on overview of the teaching of mathematics in middle school. The course lasted for 14 weeks and consisted of one 3-hour lesson a week. One of the authors of this study was the instructor of the course and determined the content of the course. One of the main course objectives was to introduce the clinical interview method for mathematics teacher development. This research was carried out within the scope of this objective for the course.

Before conducting the interviews, PSMTs were provided with theoretical knowledge and in-class practical experiences. The theoretical part of the course lasted nearly five class hours and included: (i)An introduction to Clinical Interviews including Clinical Interview Techniques and the benefits of Clinical Interviews in teacher development; and (ii) Types of Questions and Questioning Approaches (Strategies). Furthermore, the importance of asking high-level questions, particularly, probing questions as high-level questions, was focused on in the theoretical part of the course. In particular, PSMTs were informed of the importance of probing questions in extending students' knowledge beyond factual recall and in helping teachers to understand fully the details of students' mathematical thinking. Furthermore, the properties of the probing questions were explained and various examples of probing questions were presented to them.

The practical part of the course took four class hours. The PSMTs were provided with several written sample interviews selected from the relevant literature (e.g., Franke et al., 2009; Weiland et al., 2014) that had been translated into Turkish. Furthermore, the PSMTs listened to five different audiotaped interviews (each 1-3 minutes long) in which a mathematics teacher interviewed a middle school student. The PSMTs then analysed all of these interviews as a group in terms of the types of questions and questioning approaches used, and then to wrote down their evaluations on the sheets provided. After the PSMTs completed their analysis of each interview, they shared their evaluations with the class and discussed them under the guidance of the instructor.

After the theoretical and practical lectures were completed, the PSMTs were divided into groups, prepared their clinical interview protocols and then conducted their interviews with

middle school students from Grades 6, 7 or 8 of a public middle school. When they completed the interviews, they analysed their interviews to identify types of questions they had used. This process was repeated two times as the PSMTs conducted three clinical interviews at 3-4 week intervals over the course.

Participants

Twenty-two PSMTs (13 females and 9 males) in their fourth (i.e. final) year enrolled in the course were the participants of this study. All PSMTs in this course volunteered to participate in this study. PSMTs were informed about the purpose of the research and procedures and their written consent was received before they entered the research. Throughout the study, the PSMTs were asked to work in groups of two or three and there were nine groups in total. The mean GPA of these students for all courses taken in their previous work was 69.36 on a 100-point. Details for each student are found in Table 1.

Table 1
Information about the participants in each group

Group	**Gender of group member**	**GPA***	**Group**	**Gender of group member**	**GPA**	**Group**	**Gender of group member**	**GPA**
Group 1 (G1)	F (I) F(O) M(O)	73.87 76.85 76.30	Group 4 (G4)	F(I) F(O)	67.36 74.39	Group 7 (G7)	M (I) F (O) F (O)	62.11 71.57 70.64
Group 2 (G2)	F (I) F(O)	77.82 82.02	Group 5 (G5)	M(I) M(O)	76.22 48.99	Group 8 (G8)	M (I) F(O) M (I)	47.81 67.97 63.28
Group 3 (G3)	F(I) F(O)	65.66 67.06	Group 6 (G6)	M(I) M(O) M(O)	74.84 78.94 47.29	Group 9 (G9)	F (I) F (O)	79.79 53.08

* Cumulative GPA out of 100

**I (Interviewer-PSMT), O (Observer-PSMT)

Before this study was conducted, the PSMTs had completed the School Experience course where the PSMTs made class observations of teaching methods in the middle school classes during the fall semester. The PSMTs devoted 4 hours per week for class observations. Furthermore, at the time this study was conducted, they were taking the Teaching Practice course. The purpose of the Teaching Practice course was to provide the PSMTs with teaching experience within a classroom setting. The PSMTs devoted 6 hours per week to the practicum. They were expected to apply their expertise of instructional strategies, curriculum design, classroom management and assessment to their educational setting.

All of the participating PSMTs expressed that they had no prior experience in interviewing students until this study.

Procedures and Data Collection

The PSMTs conducted three clinical interviews during the course. The interviews were carried out in two phases:

The interviews. The first clinical interviews were conducted approximately six weeks after the semester began. The PSMTs then conducted interviews with public middle school students from Grades 6, 7 or 8. The PSMTs were asked to select a student from the low, average or high achievement level in their teaching practice classrooms with the help of the classroom teacher. The interviewed middle school students were the same classes where PSMTs were undertaking their practicum. The PSMTs were not required to work with the same students during the three interview experiences; so, depending on preferences or availability, they worked with either the same or different students. Three rounds of interviews at 3-4 week intervals were completed over the course of the semester. All interviews were audiotaped. The researchers chose fractions as the mathematical topic for all of the interviews. For each interview, three questions were selected from two Turkish middle school mathematic textbooks. The questions were related to (i) ordering and comparing fractions, (ii) placing fractions on the number line, and (iii) word problems with fractions (see Appendix).

PSMTs in each group took an active role either as an interviewer or an observer during each interview process. In each group, one of the PSMTs voluntarily decided to be an interviewer and this PSMT conducted all of the interviews, i.e., the interviewer(s) and observer(s) did not switch roles throughout the study. While the role of the interviewers was to conduct the clinical interviews around the three mathematical tasks, the role of the observers was to record their observations, particularly those concerning students' nonverbal responses to the tasks such as their reactions and gestures while working on the tasks.

Before conducting the interviews, the interviewer and observers worked in their groups to prepare the interview protocols. During the interviews, the interviewer gave the mathematical tasks to the student being interviewed and then encouraged the student to "think out loud" and write the solutions on the provided question sheet. After the student completed the questions, the interviewer asked questions while the observers recorded their observations. The length of the interviews and the number of questions varied according to the groups. Since some of the interviewers preferred to ask few questions rapidly, they completed their interviews in a short time. On the other hand, others preferred to ask many questions depending on the student's response; therefore, and these took a longer time.

After the interviews. Following each interview, each group generated transcripts of their audiotaped interviews. They then analysed their interviews to identify the types of questions they had asked and wrote down their evaluations on a sheet provided. Furthermore, once each PSMT group had completed their first interview, the researchers listened to and independently evaluated each group's interview. The researchers noted the question types asked by PSMTs and noted to what extent PSMTs were able to ask high-level questions (i.e. probing questions) to elicit students' thinking. Then, in order to help PSMTs improve their questioning approaches for the next interviews, the instructor of the course provided written and verbal feedback to each group between the interviews.

Data Sources and Data Analysis

The data sources for this study were the transcriptions of all of the audiotaped interviews. There were 27 interview transcripts in total for the three interviews done by the nine groups. The interviewed students' written answers to questions were also used as a secondary data source to understand the ways of thinking manifested during the interviews.

The analyses of the transcripts initially focused on the interviewers' questions. Therefore, before analyzing the data, the researchers of this study developed a list of codes based on the different types of questions identified in the literature (e.g., Franke et al., 2009; Paoletti et al., 2018; Sahin & Kulm, 2008). A random selection of interview transcripts (15 in total) was coded independently by each researcher through the developed coding list. All questions were coded into one of the question types. In order to examine for consistency, the codes were compared between the researchers and then discussed for agreement. The discussion continued until reaching a consensus by researchers. The descriptions and examples of the codes are provided in Table 2.

Table 2
The Code List Used to Categorise the Interviewer's Questions

Question Types	**Descriptions**	**Examples**
Factual Questions [FQ]	Factual questions ask students to check their recall of specific facts, rules, or procedures. They require pre-determined answers (Paoletti et al., 2018, Sahin & Kulm, 2008).	What are equivalent fractions? What kind of fraction is $\frac{7}{5}$?
Procedural-Next Step Questions [P-NS Q]	Procedural-next step questions ask students to provide mathematical information or for their next steps in a manner that is not factual (Paoletti et al., 2018)	What did you do next?; What did you find?; Which number did you use to expand $\frac{1}{4}$?
Leading Questions [LQ]	Leading questions ask students to direct their attention to specific ideas/or solution strategies. Another function of these questions is to lead students step-by-step to a desired end (Paoletti et al., 2018, Sahin & Kulm, 2008)	Can you show us by drawing the model of it?
Yes-No Questions [YNQ]	Yes-No questions require a simple Yes/No response (Kawanaka & Stigler, 1999)	Would it be easier to order fractions?
Probing Questions [PQ]	Probing questions ask students to explain their thinking, to extend their knowledge beyond factual recall, or push them to use previous knowledge to explore new concepts (Franke et al., 2009; Sahin & Kulm, 2008)	Why did you need to expand these fractions? Why did you use this operation [$\frac{6}{\frac{2}{3}}$,]?; Could you show us your solution in another way?
General Questions [GnQ]	General questions are questions that do not fit into the other categories presented in this table. These questions seek mostly to learn whether or not the student understands the question.	What is asked in the question? What did you understand?

Next, following the initial analyses, the remaining interview transcripts (12 in total) were coded, along with and recoding the previously coded interview transcripts. After coding all questions, the number of each question type asked by each group in each interview was counted, and percentages were calculated for the question types.

Secondly, in order to track the change of each interviewer's questioning approaches over the course of the three interviews, a list of questioning strategies "checklisting", "leading and instructing" and "probing" stated by Moyer and Milewicz's (2002) (see Table 3) was used.

Table 3
The Code List Used to Categorise the Interviewer's Questioning Approaches

Questioning Approaches	**Mostly used Question Types**	**Descriptions**
Checklisting	Factual Questions Yes-No Questions Procedural-Next Step Questions	Moving on from one question to the next Asking fast-paced questions and accompanied frequently by verbal checkmarks Non follow-up questions Focusing only student's computational process
Leading and Instructing	Leading (Guiding) Questions Procedural-Next Step Questions Factual Questions	Directing student's response to specific ideas or solution strategies Abandoning asking questions and starting teaching the concepts
Probing	Probing Questions	Asking follow up or non-follow up probing questions to elicit or extend student's thinking

Results

The Types of Questions Used by the Interviewers of PSMTs' Groups

The interviews varied in length from 4 to 25 minutes (Interview 1), 7 to 26 minutes (Interview 2) and 15 to 17 minutes (Interview 3). The lowest number of questions was 11 (occurred in Interview 1) and the highest number was 113 (occurred in Interview 2).

As shown in Figures 1-9, the interviewers used six different types of questions: probing questions, procedural-next step questions, yes-no questions, leading questions, factual questions and general questions. Each interviewer used at least four different types of questions during their interviews. During their interviews, while procedural- next step questions and yes-no questions were the most commonly used by most of the groups, leading questions and factual questions were the least preferred question types. Figures 1-9 display the percentage of types of questions used across the three interviews for each group.

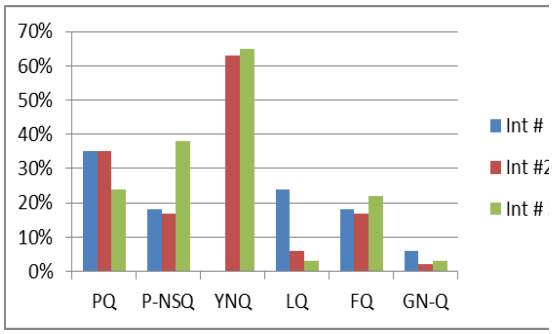


Figure 1. The percentage of Types of Questions used across the three interviews for Group 1

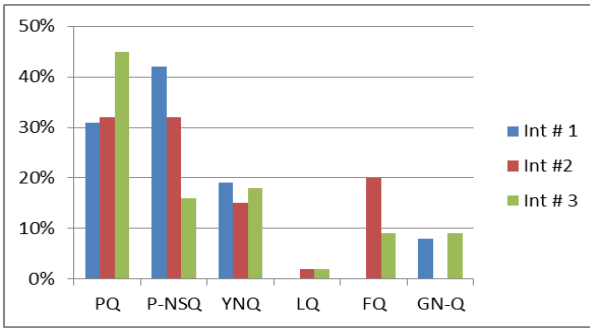


Figure 2. The percentage of Types of Questions used across the three interviews for Group 2

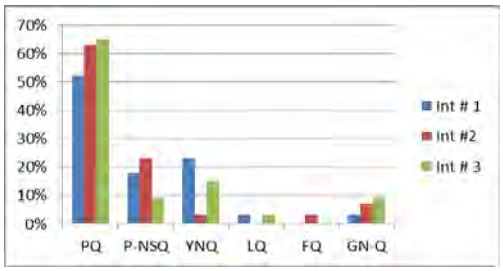


Figure 3. The percentage of Types of Questions used across the three interviews for Group 3

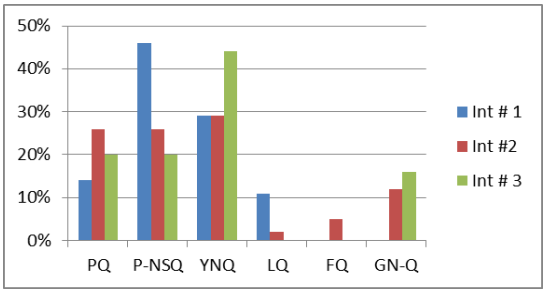


Figure 4. The percentage of Types of Questions used across the three interviews for Group 4

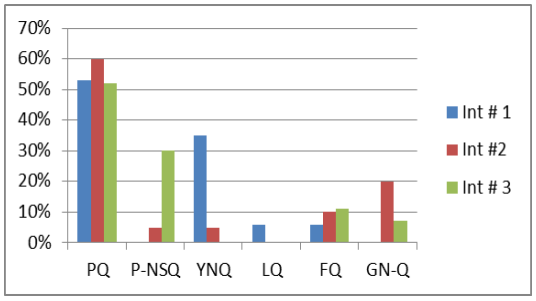


Figure 5. The percentage of Types of Questions used across the three interviews for Group 5

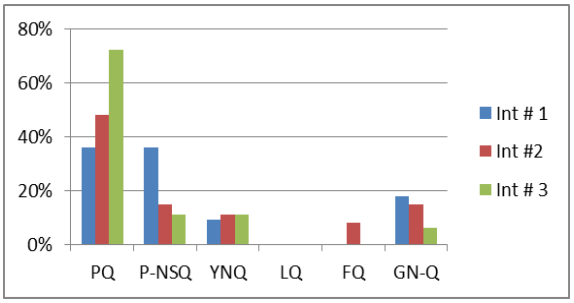


Figure 6. The percentage of Types of Questions used across the three interviews for Group 6

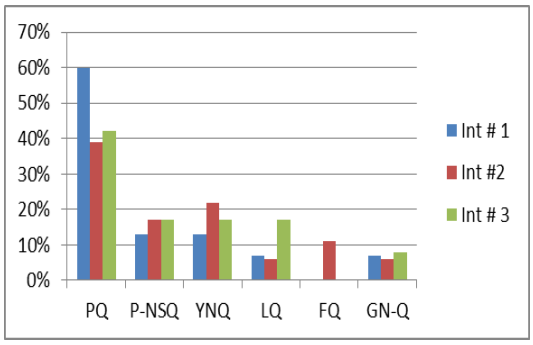


Figure 7. The percentage of Types of Questions used across the three interviews for Group 7

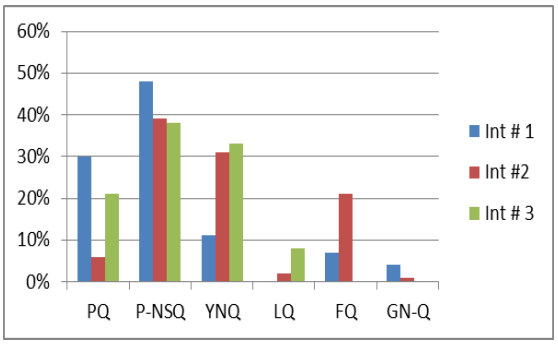


Figure 8. The percentage of Types of Questions used across the three interviews for Group 8

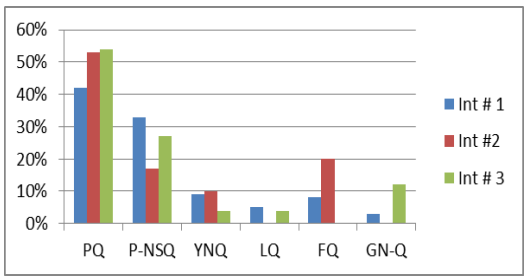


Figure 9. The percentage of Types of Questions used across the three interviews for Group 9

Questioning Approaches of the PSMTs

The qualitative analysis of PSMTs' interviews showed that whereas some of the PSMTs' questioning approaches changed, others remained the same over the three interviews. The questioning approaches of the interviewers from five groups (G2, G3, G6, G8 and G9) changed over three interviews. Four of these interviewers (G2, G3, G6, G9) changed their questioning approach towards probing student's thinking. Furthermore, one of these interviewers (G8) changed his questioning approach from checklisting towards leading student's thinking. In contrast, the questioning approach of the interviewers from the other four groups (G1, G4, G5 and G7) did not change (see Table 4). In the following section, we first report the findings regarding those PSMTs who made changes in their questioning approaches, and we then report the findings regarding those PSMTs' questioning approaches that remained the same over the three interviews.

Table 4
PSMTs' questioning approaches

		Groups of Interviewers
Questioning approaches changed over the three interviews	From checklisting towards probing student's thinking	G6
	From leading towards probing student's thinking	G2, G3, G9
	From checklisting towards leading student's thinking	G8
Questioning approaches did not change over three interviews	Leading or instructing	G1
	Checklisting	G7
	Probing	G5
	Not having a specific questioning approach	G4

PSMTs' changes in Questioning Approaches over the Three Interviews

Changing from checklisting towards probing student's thinking

The data revealed that G6's interviewer changed his questioning approach from approving student's computational process towards probing student's thinking over the course of the three interviews. As shown in Figure 6, the percentages of probing questions asked by the G6's interviewer during the three interviews were 36%, 48%, and 72%, respectively while the percentage of procedural-next step questions decreased from 36% to 11%. At the first interview, the overall tendency of G6's interviewer was to approve student's thinking instead of questioning him/her. The interviewer asked very few questions and frequently used verbal checkmarks such as "o.k." "yes," and "go ahead" [Lines 5, 9, and 11]. Therefore, the interview was often fast paced. The following episode exemplifies the interviewer's questioning approach in Task 1, Question 2 (see Appendix) during his first interview process.

1 Interviewer (I): O.k. Tell me first, what did you understand? **[GnQ]**

2 Student (S): In this question…umm…now...both of them take a break…The road is the same for both. Because the road was the same, I firstly made the denominators the same.

3 I: The same road! [The interview implies "what do you mean?"]

4 S: That is, $\frac{3}{5}$ and $\frac{4}{7}$ are on the same road.

5 I: Yes, o.k. **[verbal checkmark]**

6 S: I had to make the denominators the same.

7 I: That is, one of them has gone the $\frac{3}{5}$ and other has gone the $\frac{4}{7}$ of the same road.

8 S: Yes. Then I made the denominators of "$\frac{3}{5}$" and "$\frac{4}{7}$" the same.

9 I: Ok. **[verbal checkmark]**

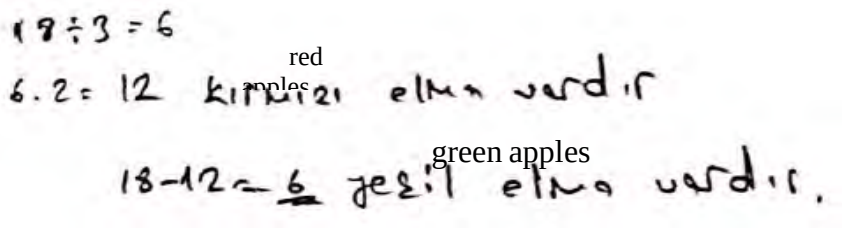
10 S: One ($\frac{3}{5}$) is $\frac{21}{35}$, and the other ($\frac{4}{7}$) is $\frac{20}{35}$

11 I: Yes. **[verbal checkmark]**

12 S: The question asks us to compare the roads they took until they got a break.

In the second interview, although the interviewer tried to ask more probing questions than he had asked in the first interview, he included an assortment of other questions, including yes-no questions, procedural-next step questions, factual questions, and general questions. By the third interview, the interviewer most commonly used probing questions. As the following episode from the G6's third interview by using Task 3, Question 2 (see Appendix) illustrates, the interviewer asked a sequence of probing questions [Lines 2, 4, 8, and 10] in order to investigate the student's thought processes.

1 S: [Student solved the question using the steps below.]



2 I: Why did you divide 18 by 3? **[PQ]**

3 S: Because the denominator is 3.

4 I: Well, you told the denominator is 3. When you divided 18 by 3, what did you want to find? **[PQ]**

5 S: Umm…I found how many apples in a safe there were. There are six apples in a safe, and 12 apples are red.

6 I: That is, here you have found one part by dividing it by 3.

7 S: Yes.

8 I: Well…why did you multiply by 2, then? **[PQ]**

9 S: Because two of the safes are red, and I have to find the green apples. I multiplied 6 by 2. It is 12. There are 12 red apples in total. Then, to find the number of green apples, I subtract 12 from 18. That is, there are 6 green apples.

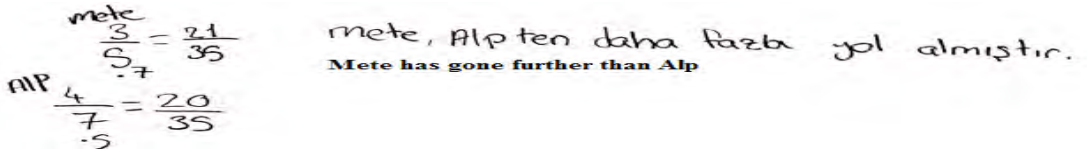
10 I: Why did you subtract 18 from 12 when you found the green apples? **[PQ]**

11 S: To find the number of green apples.

Changing from leading towards probing student's thinking

The common questioning approach used by G2's interviewer was to ask "leading" while conducting the first two interviews. As a result, the percentage of "procedural-next step questions" was high at the first two interviews as shown in Figure 2. However, the data showed that while the percentage of the procedural-next step questions decreased from 42% to 32% to 16%, respectively, the percentage of the probing questions increased over the three interviews from 31% to 32% to 45%, respectively. The following episode from the first interview illustrates G2's questioning; the question being discussed was Task 1 from Question 2 (see Appendix). Initially, the interviewer asked a general question [Line 3] to see if the student understood the question and then immediately afterwards invited the student to explain his/her answer [Line 3]. When the student explained his/her answer regarding making the denominators of the fractions the same, the interviewer responded to the student's answer by asking a probing question in order to understand exactly what the student was thinking [Line 5]. However, the interviewer did not continue to ask follow-up probing questions. Instead, she approved the student's (correct) thinking and started to ask a series of procedural-next step questions in order to learn about the student's computational procedures [Lines 7, 9, 11, and 15].

1 *I*: [The student solved the question as given below.]



2 S: [Student reads the question]. Mete will take a break after going $\frac{3}{5}$of a road, and Alp will take a break after going $\frac{4}{7}$ of the same road. Compare the distance they traveled until they took a break.

3 I: O.k., umm…what did you understand? **[GnQ]** What did you think first? **[PQ]**

4 S: I thought that I had to make the denominators the same.

5 I: Why did you make the denominators the same? **[PQ]**

6 S: To compare.

7 I: You are correct. In order to compare two fractions, the denominators must be the same. O.k., then what did you find when you made the denominators the same? **[P-NS Q]**

8 S: Mete has gone $\frac{21}{35}$ of the road, and Alp has gone $\frac{20}{35}$ of the road.

9 I: Then, what is the whole road? **[P-NS Q]**

10 S: $\frac{35}{35}$

11 I: Right. How much has Mete gone? **[P-NS Q]**

12 S: Umm…[Thinking]

13 I: Of $\frac{35}{35}$.

14 S: 21

15 I: He has gone 21 [of 35]. O.k., what about Alp? **[P-NS Q]**

16 S: 20

17 I: OK, what is asked in the question? **[GnQ]**

18 S: It asks who covers more road.

19 I: Who?

20 S: Mete.

The next episode from the third interview illustrates G2's increased use of probing questions: to follow-up on previous answers and to probe the student's correct and incorrect answers. In addition, the interviewer occasionally asked the question, "*Could you solve this question in another way*?". These probing questions [Lines 1, 3, 7, 11, and 13] were used to elicit the student's thinking about why the student preferred the division of fractions to solve the question.

1 I: How did you think? **[PQ]**

2 S: I divided 6 liters by $\frac{2}{3}$.

3 I: Why? **[PQ]**

4 S: To find the bottles. Umm.. $\frac{6}{2}$..umm..$\frac{6}{\frac{2}{3}}$. Then I multiplied 6 by $\frac{3}{2}$. Then it becomes $\frac{18}{2}$, that is, it is 9.

5 I: Here, it seems that you inverted the second fraction and multiplied the first fraction by that reciprocal. Is that right?

6 S: Yes

7 I: Why did you do that? **[PQ]**

8 S: Because it is division.

9 I: You have learnt the division of fractions as "turn upside down and then multiply," haven't you?

10 S: Yes.

11 I: Well, what is the meaning of $\frac{6}{\frac{2}{3}}$? Why did you do this operation [$\frac{6}{\frac{2}{3}}$]? **[PQ]**

12 S: Because it is $\frac{2}{3}$ of 6 liters.

13 I: What do you mean? **[PQ]**

Unlike the G2's interviewer, over 50% of G3's interviewer used probing questions throughout all three interviews (52%, 63% and 65% respectively). Figure 3 shows that this interviewer also used procedural-next step questions and yes-no questions. The interviewer did not use a sequence of probing questions but used different type of questions depending on the nature of the student's explanations. She usually used "what" questions to learn about the student's thinking but did not attempt to ask "how" questions to learn more about how the student thought. She also occasionally used affirmative expressions such as "o.k." and "go ahead." The data showed that the probing questions asked during the second and third interviews were more of a follow-up nature. The following episode from the third interview of G3 by using Task 3, Question 2 (see Appendix) illustrates how the interviewer used a probing sequence to make explicit the student's correct strategy. As shown in this example, the interviewer began by asking a probing question [Line 1] to understand exactly how the student thought because she was unclear about the student's written solution. Then she used a series of probing questions [Lines 7, 9, 13, and 15] to make explicit the steps used in the student's solution and to highlight the mathematics involved.

1 I: Could you explain to me how did you think? I don't want to misunderstand you. **[PQ]**

2 S: There are 18 apples.

3 I: Uh-huh.

4 S: The apples were divided by three, and two of them were red [student means that 2/3 of the 18 apples are red]

5 I: Uh-huh.

6 S: I had to find one [the student means 1/3 of the apples].

7 I: Why did you have to find one? **[PQ]**

8 S: Umm…otherwise, it was more difficult to find how many.

9 I: Well, how did you understand that the one [1/3] of the apples was green if they were divided by3? **[PQ]**

10 S: Because 3/3 is a whole. It equals 18.

11 I: Uh-huh.

12 S: If we subtract 2/3 from 3/3, we will find the green apples. That is 1/3. Because 1/3 equals 6, the answer is 6.

13 I: Well, how do you show that your solution is correct? **[PQ]**

14 S: In the same way.

15 I: Could you show that in another way? **[PQ]**

16 S: I do not remember at the moment.

Similar to the G3's interviewer, the G9's interviewer's percentage of probing questions increased over the three interviews (42%, 53% and 54% respectively; Figure 9). The data indicate that the interviewer asked several probing questions to learn about the student's thinking the interviewer did not follow up on the student's thinking.

Changing from checklisting towards leading student's thinking

The data show that whereas the common questioning approach of G8's interviewer was "checklisting" in the first interview process, it was either "leading" or "instructing/teaching" in the second and third interviews. Procedural-next step questions were dominant over the three interviews (48%, 39%, and 38%, respectively). Furthermore, the percentage of yes-no questions increased, and the percentage of probing questions did not increase as the study progressed and was quite low (6%). As shown in the following episode, the interviewer focused mainly on computational procedures and therefore used mostly procedural-next step questions. In this episode from the first interview (Task 1, Question 1 in Appendix), the interviewer invited the student to explain his/her thinking initially by asking a probing question [Line 3]. Then the interviewer responded to the student's response with another probing question [Line 4]. However, after the student provided the correct answer, the interviewer stopped asking probing questions and continued asking procedural-next step questions [Lines 7, 9, 11, and 13] to learn more about the student's mathematical process.

1 I: O.k. You solved the question.

2 S: Yes.

3 I: How did you figure out that answer? Could you explain it to me? **[PQ]**

4 S: Firstly, I made the denominators of these fractions the same. The fraction is larger if its numerator is bigger. That is, $\frac{1}{3}$ is bigger than $\frac{1}{4}$.

5 I: Well, how did you equalize the denominators? **[PQ]**

6 S: I multiplied $\frac{1}{3}$ by 4, and $\frac{1}{4}$ by 3.That is, I expanded the fractions.

7 I: Well, what did you find when you multiplied by 4? **[P-NS Q]**

8 S :$\frac{4}{12}$.

9 I: What did you find when you multiplied by 3? **[P-NS Q]**

10 S: $\frac{3}{12}$.

11 I: Right. Which one is bigger? **[P-NS Q]**

12 S: $\frac{4}{12}$.

13 I: Which one is $\frac{4}{12}$? [$\frac{1}{3}$ or $\frac{1}{4}$] ?**[P-NS Q]**

14 S: $\frac{1}{3}$.

In addition, in several instances, it was observed that the interviewer shifted from questioning to providing instructions during interviews, i.e., they abandoned the questioning strategy and attempted to explain the solution.

PSMTs' Questioning Approaches that Remained the Same over the Three Interviews

Leading or instructing as common questioning approach

It was observed that the common questioning approach used by G1's interviewer during the three interviews was "*leading,*" i.e., the interviewer usually directed the students' responses. Furthermore, the percentage of procedural-next step and factual questions used by the G1's interviewer increased over the course of the three interviews. Although the data showed that the percentage of the leading questions used by interviewer decreased, in a variety of instances these questions, with factual questions and procedural-next step questions, were used to direct the students' response or to provide hints about the correct answer. Using these kinds of questions, she led the students into thinking the way she wanted them to think. Even when G1's interviewer used probing questions, she did not ask another probing question to follow up on the student's thinking and the questions related mainly to understanding the student's mathematical procedures rather than his/her thinking process. In addition, the percentage of probing questions decreased from 35% in the first interview to 24% at the third interview. The following episode shows the questioning process of G1's interviewer during the first interview. Here the interviewer asked a specific probing question to learn about how the student decided $\frac{1}{3}$ is larger than $\frac{1}{4}$ [Line 3]. Once the student explained his/her answer, the interviewer asked the student a leading question about drawing a model rather than asking another probing question [Line 5].

1 S: [Student reads the question] Compare. What fraction is larger, $\frac{1}{3}$ or $\frac{1}{4}$?

2 S: [Student answers] $\frac{1}{3}$ is larger.

3 I: Well, how did you get it? What did you do? **[PQ]**

4 S: A road is divided into four and one part is taken. For example, when the road is divided into four parts, one part becomes smaller.

5 I: Right, can you show it to us by drawing? **[LQ]**

6 S: Yes.

7 I: O.k.

Furthermore, during the second and third interviews, the G1's interviewer maintained her questioning process. The following episode from third interview of the G1's interviewer exemplifies the use of a series of procedural-next step, factual, and leading questions in order to understand the students' mathematical procedures and to help him/her discover the answer.

1 I: What did you find? **[PQ]**

2 S: I added two fractions and found $\frac{12}{12}$

3 I: Could you check your calculations again? What did you do here? **[P-NS Q]** Expand with 4?

4 S: Yes.

5 I: It is $\frac{8}{12}$?

6 S: Yes.

7 I: What did you do here? **[P-NS Q]**

8 S: I expanded with 3.

9 I: It is $\frac{3}{12}$?

10 S: Yes.

11 I: Then you added. What did you find? **[P-NS Q]**

12 S: $\frac{11}{12}$.

13 I: Well, what does $\frac{11}{12}$ show/give us? **[FQ]**

14 S: It gives us the total number of cultivated tomato and cultivated pepper fields.

15 I: Well, what does the question ask? **[GnQ]**

16 S: It asks for the cultivated onion area. It is $\frac{1}{12}$.

17 I: Well…can you show it by drawing a model? You can draw a garden/field and show which parts include tomatoes, peppers, and onions. **[LQ]**

18 S: [Student draws a rectangle and divides it into parts as follows.] This part is pepper, this part is tomatoes, and this part is onions.

Checklisting as a common questioning approach

The common approach exhibited by G7's interviewer across the three interviews consisted largely of "checklisting." Although the data showed that the most frequent type of question used by the interviewer was the probing type, particularly in the first interview process, the percentage of the probing questions decreased over the course of the study. Furthermore, in each interview, the interviewer did not use different probing questions. He used the same probing questions each

time, which were "*Why did you think so?*" and "*Can you solve this question by another way*?" Further, he did not engage in follow-up to further investigate the student's answer. When the interviewer obtained either an ambiguous or incorrect answer from the student being interviewed, he mostly moved on without further probing the student's thinking. The interviewer also frequently repeated or rephrased the response provided by the student for approval. All of the interviews carried out by this interviewer were fast-paced (4 to 7 minutes) and were accompanied by frequent verbal checkmarks. The interviewer moved from one question to the next with little regard for the student's response. This is illustrated in the following episode from the first interview, where the G7's interviewer asked a question before the student finished his/her explanation [Line 4].

1 S: [Student reads the question] Compare. What fraction is larger, $\frac{1}{3}$ or $\frac{1}{4}$?

2 I: O.k.

3 S: Here, we write the fractions $\frac{1}{3}$ and $\frac{1}{4}$. If we cross multiply…

4 I: Why did you think so? **[PQ]**

5 S: Because we learnt so.

6 I: O.k., go ahead. **[verbal checkmark]**

7 S: When I multiply 4 with 1 and also 3 with 1, then 1/3 is bigger.

8 I: Good **[verbal checkmark]**. Well, could you solve this question in another way? **[PQ]**

9 S: Umm…we can solve it by making the denominators the same. We find the same result at that time.

10 I: Well, what does it tell us if we make denominators the same? **[P-NS Q]**

11 S: It says that 1/3 is bigger [than ¼].

12 I: How do you know? **[PQ]**

13 S: Because when I multiply 1 and 4, 4 is bigger.

14 I: Good. **[verbal checkmark]** Well, another way? How can we solve this question in another way? **[PQ]**

15 S: We can solve by drawing.

16 I: O.k. Good. **[verbal checkmark]** Can you show it to us?

Furthermore, the interviewer used the verbal checkmarks "good", "right" or "o.k." before moving on to the next idea. These verbal checkmarks were indicators that the interviewer did not expect the student to think about and respond further to the previous question.

Probing as common questioning approach

G5's interviewer used a majority of probing questions over all three interviews to elicit the student's thinking when they gave correct or incorrect answers. The data display that the percentage of probing questions asked by the interviewer was the highest in the second interview. It is notable that the interviewer did not ask any leading questions during the second and third interviews. On the other hand, the interviewer did make frequent use of either yes-no or procedural-next step questions. The percentage of the yes-no questions was high (35%) at the first

interview and the percentage of procedural-next step questions (30%) was high at the third interview (Figure 5).

Not having a specific questioning approach

The data showed that the G4's interviewer used an assortment of questions in each interview, including probing questions, yes-no questions, procedural-next step questions, leading questions, and general questions. The most preferred questions type of the G4's interviewer was yes-no questions during all three interviews and the use of these questions increased from the first to third interview (Figure 4). The interviews were often fast-paced and lacked follow-up probing questions. The interviewer appeared to be mainly in learning about the students' mathematical procedures. Furthermore, although the percentage of the probing questions increased in the second and third interview compared to the first interview, the overall percentage of probing questions remained low, and the probing questions that were asked were not followed up. When the interviewer obtained an answer from the student she simply moved on to the next question without always waiting for the student's responses.

Discussion and Conclusions

The findings of this study displayed what types of questions were used by PSMTs as they conducted interviews with students and in what ways their questioning approaches changed as they conducted interviews three times over a semester.

The PSMTs used six different types of questions over three interviews ranging from yes-no questions to probing questions. The procedural-next step questions and yes-no questions were the most preferred questions by most of the PSMTs during their interviews. Whereas all of the interviewers in this study attempted to use probing questions during their interviews they did not pose many of these, particularly during their first and second interviews. This is in line with the results of several studies, which reported the tendency of mathematics teachers to ask closed and low-level cognitive questions rather than higher-order cognitive questions (e.g., Boaler & Brodie, 2004; Brualdi, 1998; Sahin & Kulm, 2004). On the other hand, our findings revealed that among the nine groups, the interviewers in four groups, G2, G3, G6, and G9, increased the number of probing questions over the course of three interviews. Furthermore, the interviewers of G2, G3 and G6 also attempted to use follow-up probing questions that targeted to learn more about students' thinking.

Our findings indicate that is possible to change PSMTs' questioning approaches towards probing student's thinking within the context of face-to-face interaction with students through clinical interviews. Five of the interviewers changed their questioning approaches over the course of three interviews. While four of these interviewers' questioning approaches changed towards probing student's thinking, one of these interviewers changed his questioning approach from checklisting towards leading student's thinking. This finding is in line with Weiland et al.'s study (2014), in which the participating pre-service teachers changed their questioning practice and improved in their abilities to competently pose follow-up probing questions to elicit students' in-depth thinking. However, the careful design, structure and support of the interview experience of PSMTs are crucial factors in the context of clinical interviews (Crespo & Nicol, 2003). In this study, the intervention might have helped several PSMTs increase the quality and quantity of the probing questions asked during the interviews and change their questioning approaches towards probing student's thinking. In this study, PSMTs were taught about questioning, types of questions, and the importance of asking probing questions in class before conducting their own

interviews. Hence, they were aware of the different question types and the importance of asking probing questions when they started their own interviews. Theoretical knowledge and practice provided in the course may likely have helped the change of several PSMTs' questioning approaches towards probing students' thinking. In addition, as stated in the Schwartz (2015) and Weiland et al.'s (2014) studies, the feedback given by the instructor of the course after they completed their first and second interviews may have been another factor that supported some of the PSMTs' change since the feedback was intended to encourage PSMTs to use probing questions to elicit student's thinking during their interviews. As Weiland et al. (2014) discussed, the appropriate scaffolds can change PSMTs' questioning approaches in terms of asking competent questions. Furthermore, having PSMTs work within a collaborative learning environment may have supported the interviewers' change of questioning approaches in terms of asking probing questions. Although the interviewer for each group asked the questions without any interventions from the observers during the interviews, they worked in their groups to perform all of the given activities before and after conducting their interviews. While preparing their interview protocols before conducting each interview, the group members decided together on the possible answers of students and the questions that they would like to ask in response to students' answers during the interviews. Furthermore, the group members analyzed and discussed the interview process together after they conducted the interviews. If all of the group members communicated and contributed to the group work, their shared experiences may have contributed to the change of their interviewers' questioning approaches.

There may be other reasons behind the change of questioning approach of these interviewers towards probing student's thinking. The PSMTs' change in terms of asking probing questions can perhaps be explained by the extent of their content knowledge (CK) and pedagogical content knowledge (PCK). As several researchers (e.g., Groth et al., 2016; Heng & Sudarshan, 2013; Martino & Maher, 1999; van den Kieboom, Magiera, & Moyer, 2014) have indicated, knowledge of students and knowledge of content may play roles in formulating spontaneous probes. Van den Kieboom et al. (2014) explored pre-service teachers' algebraic thinking and the questions posed during one-on-one interviews. They found that whereas the pre-service teachers with lower algebraic thinking proficiency could not ask probing questions, the pre-service teachers with higher algebraic thinking were able to ask probing questions in order to examine student thinking. In this respect, in our study, the GPAs of the interviewers, who changed their questioning approaches towards probing students' thinking (G2, G3, G6, G9), are considered in terms of CK and PCK. It is seen that, with the exception of the G3's interviewer, the GPAs of these interviewers are above the group average. On the other hand, when the GPAs of the interviewers who failed to improve their probing questioning approaches (G1, G4, G5, G7, and G8) are considered, with the exception of the G1's interviewer, these GPAs are below the group average. Of course, a high GPA is not a guarantee of profound mathematical CK and PCK in regard to fractions and other content, however, this finding indicates that CK and PCK could potentially serve as indicators of abilities to ask probing questions. As this study did not aim to address PSMTs' CK and PCK, future research is needed to investigate the relationship between PSMTs' CK and PCK and the questions they use during the clinical interviews.

Our data also indicated that conducting three clinical interviews was not adequate in terms of changing several PSMTs' questioning approaches, particularly, in terms of changing towards probing student's thinking. Our findings displayed that the questioning approach of four interviewers remained the same over the course of three interviews. As in the case of mathematics teachers and pre-service mathematics teachers participating in other studies (e.g., Moyer & Milewicz, 2002; Sahin & Kulm, 2008), our findings revealed that the common questioning approaches of several interviewers (G1, G4, G7 and G8) included checklisting, leading, or

instructing during the interviews. Although the interviewers from these four groups used probing questions occasionally during their interviews, they did not increase their use of probing questions as the interviews progressed. These findings indicate that asking follow-up probing questions may be a demanding task for these novice PSMTs since they had no prior experience in interviewing students at the beginning of the study. On the other hand, surprisingly, some of the interviewers' use of probing questions decreased as the interviews progressed, despite instructor feedback. The possible explanation of this finding may be PSMTs' previous experiences regarding the use of closed and factual questions and not getting enough exposure to probing questions. Other factors that may have affected the PSMTs include working with different students for each interview and that each interview involved fractions. As this study did not aim to address which factors helped them to change their questioning approaches and which factors hindered their changes during their clinical interview experiences, future studies could examine the PSMTs' reflections on these factors in detail through interviewing them about the reasons of their choices of question types and questioning approaches.

The act of asking a good question is cognitively demanding (Boaler & Brodie, 2004), and the development of the art of questioning may take years (Martino & Maher, 1999). This study only followed the PSMTs for a semester-long course, and, as our findings suggest, novice PSMTs should be followed for a longer period. The study suggests that more time and more experience are needed for PSMTs to be able to ask probing questions to elicit, understand, and foster student's thinking.

As many researchers (e.g., Crespo & Nicol, 2003; Dunphy, 2010; Groth et al., 2016; Heng & Sudarshan, 2013) have highlighted, these research findings support the claim that conducting clinical interviews around mathematical tasks may be a valuable activity for PSMTs in terms of practicing questioning and developing their questioning approaches towards probing student thinking, therefore, this method should be used in PSMTs' training. Longitudinal studies can provide stronger evidence of the utility of the clinical interview method for PSMTs.

Disclosure statement

The authors declare that there are no potential conflicts of interest with respect to the research, authorship, and publication of this article.

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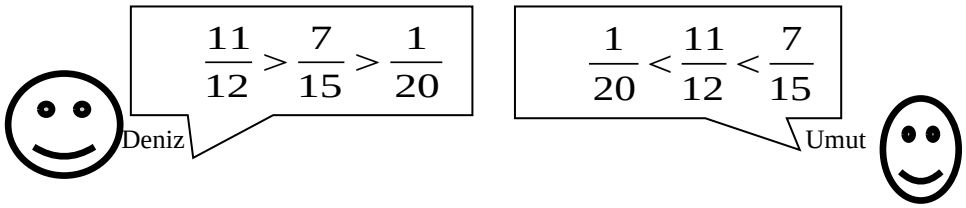
Appendix

TASK 1

Question 1: Compare, which fraction is larger, $\frac{1}{3}$ or $\frac{1}{4}$?

Question 2: Mete will give a break after going $\frac{3}{5}$ of a road and Alp will give a break after going $\frac{4}{7}$ of the same road. Compare the road they took until they gave a break.

Question 3: The fractions, $\frac{1}{20}$, $\frac{7}{15}$ and $\frac{11}{12}$, are given. Deniz and Umut sort the fractions taking into account their proximity to 0, and 1. Determine whose answer is correct.



TASK 2

Question 1: Show the fractions $\frac{3}{8}$ and $\frac{3}{4}$ on the same number line.

Question 2: Show the fractions $2\frac{1}{3}$ and $\frac{7}{5}$ on the same number line.

Question 3: Specify the fractions indicated by the letters A and B on the number line above.

TASK 3

Question 1: $\frac{2}{3}$ of a garden is planted with tomatoes and $\frac{1}{4}$ of it is planted with pepper. As the onion is planted in the remaining parts, find out what the entire area of the onion planted area is as a fraction.

Question 2: Find the number of green apples in a safe, while $\frac{2}{3}$ of the 18 apples are red, the rest are green apples.

Question 3: 6 liters of orange juice will be filled in $\frac{2}{3}$ liter bottles. Find out how many bottles are required for this.

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