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How does online professional development nurture teachers' noticing skills of students' thinking?: The case of data analysis

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This paper presenting one aspect of a design-based research project examines the development of a teacher's noticing skills in the context of data analysis and interpretation during her involvement in an online professional development program (OPD). For this purpose, the noticing skills of the teacher for the strategies used in the given students' responses were identified according to the modified version of the Jacobs et al.'s (2010) framework. By examining the teachers' discussions in the OPD, how the teacher's noticing expertise evolved throughout this process was investigated. Findings showed that the teacher had difficulties in each interrelated skill of noticing at first. However, enhancement in her noticing of students' thinking in the context of data analysis was observed throughout her participation in the OPD.

Keywords: Collaboration, data analysis and interpretation, online professional development, teacher noticing.

Teacher noticing is a key part of teaching expertise (van Es & Sherin, 2021) and has been a prominent construct in the mathematics education literature for the last 20 years. It is generally defined as all the processes that teachers engage in to deal with the ongoing information in the classroom (Sherin, Jacobs, & Philipp, 2011). Teacher noticing is essential for efficient instructional practice (Blömeke et al., 2015) and has a direct influence on students' learning (van Es & Sherin, 2021). Although different conceptualizations about teacher noticing exist, it is generally examined as including two main processes: paying attention to and making sense of the notable situations in the classroom (Sherin et al., 2011). Jacobs and her colleagues (2010) add one more process to the above description, which is decision-making. Furthermore, they focus particularly on noticing students' mathematical thinking. While the first process in Jacobs et al.'s (2010) conceptualization, attending, is about identifying the significant details in the students' strategies, the second process refers to the explanation of the students' understanding by making sense of the details in their strategies. The reasoning that teachers use when deciding how to respond based on the students' understanding is examined under the third process.

Also, the relevant studies suggest that noticing is not an innate ability, and the teaching experience alone does not provide sufficient improvement (Jacobs et al., 2010). Therefore, researchers attempted

to develop teachers' noticing skills through variety of ways. For instance, Fernandez et al. (2020) showed evidence of enhancement in prospective teachers' noticing skills through sharing narratives about their own practices in an online forum and collaborating with their partners and tutor. Moreover, several other researchers (e.g., Klein et al., 2017) agree that online systems "slow down the process of learning" (Clay et al., 2012, p. 762) by giving teachers extra time to reflect on the situations. These systems also allow teachers from different contexts to collaborate around instructional situations. The necessity for such environments has been felt even more during the COVID-19 pandemic. Therefore, in this paper, we report one aspect of a large research project which aims to support middle school mathematics teachers' noticing skills of students' mathematical thinking through an Online Professional Development Program (OPD).

Although we focus on various mathematical contents in the project, the specific domain of students' mathematical thinking considered in this paper is about analyzing and interpreting data which is the core process of the statistical reasoning (Jones et al., 2004). More specifically, this process includes "recognizing patterns and trends in the data and making inferences and predictions from data." (Jones et al. 2004, p.103). In this paper, our aim is to examine to what extent a middle school mathematics teacher attends to and interpret students' inferences from given data and how she bases her instructional decisions on students' understandings. Moreover, we are interested in how her participation in the OPD can support the development of her noticing skills by answering the following research question: How does a middle school mathematics teacher's noticing of students' thinking in the context of analyzing and interpreting data develop throughout an online professional development program? We believe that this study would provide valuable information to the teacher noticing literature about the nature and development of middle school mathematics teachers' noticing skills through the OPD.

Different from the studies that use online systems for developing teachers' noticing skills (Fernandez et al., 2012; Fernandez et al., 2020), synchronous modes of communication have been also used in the present study. Furthermore, in this research, we work with in-service teachers who have less than 15 years of experience. By this way, we have a chance to investigate novice teachers' development of noticing skills regarding students' understanding through collaboration with other colleagues from different schools across Turkey. Lastly, we particularly focus on the content of data analysis and interpretation, which receives relatively less attention in the available literature.

Method

This study is part of a large research project, which adopts design-based research as its methodology (Bakker, 2018). In the current study, there was only one participant, Asli, and we examined how her noticing skills developed through the interaction with other mathematics teachers in the OPD. The program was developed in line with basic design principles involving collaborative inquiry in the community and the value of individual ideas, autonomy in self-learning and development, and giving feedback during the process. The OPD took place in an environment where teachers could asynchronously access (read/watch/listen) the given contents and each other's ideas as well as commenting on them weekly via Microsoft Teams. The Program also included synchronous school mathematics topic-focused meetings related to the given contents.

Participants

Aslı was selected among the project participants, 35 middle school mathematics teachers, with up to 15 years of teaching experience in public schools in different cities of Turkey. We selected Aslı, who has 8 years of teaching experience, for this study because her noticing skills were low at the beginning and she was one of the most active teachers in the OPD. She tried to enhance a collaborative discussion environment by challenging the other teachers through her questions and making comments about their opinions.

Data collection

In the present study, data was collected through the basketball problem, shown in Figure 1. This problem was adapted by Gökce (2019) from the work of McGatha et al. (2002). In the problem, the scores of two basketball players during the last 10 games were given to the students, and they were asked to decide which player the coach should choose. To make a decision, students needed to analyze the given data by using appropriate measures of central tendency and variability, and then interpret the results in the given context. Based on two common strategies used by students for answering such data comparison tasks, two students' responses are provided under the problem for the purpose of examining teachers' noticing skills. As shown in Figure 1, Student 1 (S1) chose Barış by focusing on the mean score of each player. Her reasoning was partially correct since she ignored the variability of the given data. Student 2 (S2) also chose Barış by only focusing on the scores above a certain value, 15. Yet, the reasoning of S2 was not correct since he ignored the data less than 15.

The coach will select one player from the school's basketball team to play in the all-star tournament. Below is a listing of points scored by the two candidates, which the coach thinks choosing, for the last ten games of the season.

Players	Points Scored in Games									
Arda	8	14	11	13	15	12	10	10	9	13
Barış	4	15	8	17	18	9	19	6	18	5

Which player would you recommend the coach choose? Explain why.

Your students, Student 1 and Student 2, responded as follows:

Student 1 (S1)'s response: He should choose Barış because while Arda's average is 11.5, Barış's average is 11.9.

Student 2 (S2)'s response: He should choose Barış because he scored 15 or more in half of the games that he played.

Figure 1: The basketball problem

To determine the teachers' noticing skills prior to the discussions in the OPD, they were asked to answer three questions suggested by Jacobs et al. (2010) individually. Their responses to those questions constituted the pre-test of this study. Then, various discussions were held about the basketball problem with all teachers and the research team in the OPD for 3 weeks. To summarize the discussions in the OPD, a synchronous session was conducted by the facilitator, a member of the design team who has expertise in statistics education. In that session, the teachers were expected to ask any questions they had in their mind regarding the problem and state their opinions as to the asynchronous discussions held among the teachers. Moreover, the facilitator highlighted some major points, such as the importance of the context in making decisions based on data, which did not get enough attention in the asynchronous discussion. Lastly, semi-structured one-on-one interviews were conducted to get in-depth information regarding the change in the teachers' noticing skills after asynchronous and synchronous discussions. Briefly, Aslı's written responses about two students' strategies, participating teachers' comments in the asynchronous discussions held in the OPD and summary session, and Aslı's interview transcripts were the data for this study.

Data Analysis

For the analysis of the data, the theoretical framework by Jacobs et al. (2010) was modified by taking into consideration the data collected and the Teacher Recognition Skills framework developed by Kilic and Dogan (2021). Accordingly, while teachers' attending skills were examined at four levels, the skills of interpreting students' understanding and deciding how to respond were examined at five levels as indicated in Table 1. Based on this framework, we firstly determined the noticing skills of Aslı. Then, by examining the teachers' discussions in the OPD and the interview of Aslı, we tried to find evidence in the development of her noticing skills and how those developments occurred.

Table 1: The modified version of the Jacobs et al.'s (2010) framework

Professional noticing skills	Attending	Interpreting	Deciding
Levels	No attempt	No attempt	No attempt
	Lack	Lack	Ignorance
	Limited	Limited	Questioning
	Robust	Substantial	Challenging
		Robust	Responding to child and incorporating

Findings

In this paper, we focus on Aslı's development of noticing skills during her engagement in the OPD. Aslı's responses and the changes in her ideas during and after the discussions in the OPD will be provided for each noticing skill.

The teacher's evolving expertise in attending and interpreting skill

The following response presents teacher's attention to the given students' strategies before the discussion in the OPD:

For S1, the mean is the best way while comparing two groups. For S2, if the range is too much among the given data, it is correct to use the median and the data which are above the median. We can say that statistical reasoning of S2 was correct if we just evaluated the player Barış. However, if the range is not too much while comparing two groups, as in the two groups in this question, a comparison using the mean will be a better approach just like the strategy of S1. (Pre-test)

In this response, Aslı attended that S1 used the mean while comparing two groups but could not notice that she did not consider the variability while interpreting the given data. Since Aslı could not attend all the details in S1's strategy, she evaluated student's reasoning inaccurately. She attended S2's incorrect reasoning; however, she focused on a concept, median, which was not used by the student. Therefore, the level of the teacher's attention to the given student strategies was evaluated as lack.

Aslı began the discussions in the OPD by responding with the same arguments she provided in the pre-test. After her comment, T1 responded, and the following discussion was held among some teachers:

T1: ...I believe that S2 chose Barış by considering the mode of the given data. Even though the answer of S2 is correct, I do not think that his reasoning is true.
 Aslı: If S2 used the mode of the given data, should he not has considered 18 [the mode of Barış's scores]? If S2 had used mode, would he not have said that 18 was

repeated more in the given situation, and thus, I chose Barış? I thought that since the sixth data is 15 when all of them are ordered, S2 focused on the median of the given data.

T1: I thought that S2 used the mode by grouping all the data, which are above 15. I do not think that we can take 15 as the median since there are 10 games in total.

T3: Different from the discussions above, I think that neither S1 nor S2 reasoned correctly in this problem. S1's reasoning is incomplete since she does not know that it is not enough to just look at one central tendency measure when the averages are so close to each other. Here, she should have looked at the range of the given data additionally. I could not understand which statistical concept S2 used with his statement of '15 and more points'. I do not think that he used the mode, or the median as mentioned in the aforementioned comments.

In the subsequent comments, teachers did not seem to agree on evaluating S2's strategy. Hence, the facilitator posed some questions to encourage teachers to think about the meaning of mode and median for the given data sets. After a long discussion in the OPD, teachers came to an agreement that S2 did not use the concepts of mode or median, but simpler reasoning, i.e., he only concentrated on the higher points in the given data set. The following comment of Aslı in the discussion indicated that teacher's expertise in attending S2's strategy improved as a result of her online interaction with other teachers.

I believe that organizing data by grouping [with respect to higher and lower scores] is a correct reasoning to understand the nature/tendency of the data, but incomplete. This is also true for S2. While thinking the scores which are above 15, the data which are below 15 were lost. (Discussion)

With regard to teacher's interpreting skills, Aslı's initial response indicated lack of evidence in interpreting the students' mathematical understanding. The following response was given before the discussions in the OPD when Aslı was asked to interpret the students' mathematical understanding by considering the students' strategies:

For S1, the mean; that is, all values in the data set, is important because it is affected by the change of each data. For S2, on the other hand, if the difference between the data is high, looking at the median and the data above the median is a more accurate way of interpreting the data. Because of the slightly skewed distribution of the data, looking at the median is the most useful method for S2. (Pre-test)

Although Aslı thought that S1 considered the importance of all data values, S1's response was not enough to make this claim. For S2's strategy, the teacher again focused on the concept of median as she attended in the first question. She argued that S2 knew using the median when the data set was skewed; but this cannot be concluded from the student's strategy. Furthermore, the teacher did not mention variability or representativeness while interpreting the students' mathematical understanding.

When the teachers were asked to interpret students' mathematical understanding in the given student responses in the OPD, Aslı's comment was as follows:

S1 used only the mean when comparing the data groups, but did not include the concept of range, she should interpret these two concepts together. In S2's interpretation, grouping [with respect to highest and lowest scores] can be used to organize the data, but it is insufficient on its own for data analysis. It is seen that S2 has no knowledge of the concepts of mean, median, and range when looked at his solution. I think that the starting points of both students' reasoning are correct, but they are insufficient. To interpret the data with a single concept will not be sufficient in data analysis. (Discussion)

Most of the other teachers agreed with Aslı's comment in the following parts of the discussion. In her comment, Aslı mentioned the concepts of mean and range, which are necessary to interpret the mathematical understanding of S1's strategy. As for understanding S2's strategy, Aslı gave up her idea of median. Since the teachers did not focus on the meaning that S1 attributed to the mean, the facilitator prompted teachers to discuss this point through her questions. After this discussion, she interpreted S1's strategy by referring to the concept of representativeness during the post interview while she did not mention this in her first comment in the OPD. Lastly, Aslı's following reflection regarding her own development gave us one more evidence that the discussions in the OPD nurtured her interpreting skills of students' understanding. "The discussions in the OPD enabled us to brainstorm. It made me realize some new ideas. In particular, I became aware of the concept of range for this question". (Interview)

The teacher's expertise in deciding skill

Before the discussions in the OPD, Aslı explained her next instructional moves as in the following:

To show that both students' reasoning can differ with respect to the different situations, I give two data sets whose ranges are high and low and I ask which student is more successful. For example,

Case 1: Ayşe's savings during five months: 10, 50, 90, 90, 100 (Mean=68)

Case 2: Ali's savings during five months: 70, 80, 85, 85, 100 (Mean=84)

If we look at the mean, we interpret correctly and say that Ali is more successful. I can relate this question with the given problem situation by stating that it is not correct to say that Ayşe is more successful since she has 3 data which are above 90. (Pre-test)

In the interview, Aslı added that the above example was for S2. With this response, she believed that the use of mean was better for this problem context. Thus, she asked such a question to S2 so that he can realize that he should use the mean while answering both the above and basketball problem. It seems that her aim of asking this question is to lead S2 to the correct answer. In addition, Aslı added some questions to understand both students' strategies better such as "Why did you use 15 in your answer?" or "Why did you use the mean?". For these reasons, the level of her expertise in deciding how to respond based on the given students' strategies was determined as questioning.

During the asynchronous discussions in the OPD, Aslı began with the following argument:

S1 should feel the need to look at the range while interpreting the data. So, for this purpose, I would ask which players she would choose if their means were equal. Similarly, I would ask S2 which players he would choose if the number of data, which are above 15, was equal. My aim in this part is for S1 and S2 to notice that their reasoning is missing and only one method is not enough while analyzing data. (Discussion)

Different from her first comment in the pre-test, Aslı asked some probing questions to S1 to allow her to notice that she should consider the variability of the given data. In the same way, the questions for S2 were to guide him to consider the data which are below 15. In other words, the teacher started challenging students, a higher level in the framework (see Table 1), to help them realize that their reasoning is underdeveloped. Although Aslı did not comment on guiding S2 to the use of average in her first explanation in the OPD, she offered some instructional moves after the facilitator's questions. On the other hand, during the interview, when she was asked what problems, she would form next, she stated that "I would again present a problem that students can provide different comments for...Indeed, I would change the context. However, the characteristics of the data would be the same

were calculating just the mean would not be sufficient.” With this description, we can say that the teacher decided to provide new contexts for students. However, her aim seems to make students practice the ideas discussed in the given problem, not to emphasize the importance of the context, which was discussed by the teachers and the facilitator during the synchronous session.

Discussion

The case of Asli was presented to illustrate how the OPD helped teachers in their development of noticing skills in a collaborative environment. In the beginning, Asli had difficulties in each interrelated skill of noticing. However, the findings showed enhancement in her noticing of students’ thinking in the context of data analysis throughout her participation in the OPD. During the discussions, teachers had a chance of observing different ideas, posing questions, and making suggestions to each other. Also, the facilitator encouraged teachers to focus on the important concepts through her prompts such as asking questions about the meaning of central tendency measures in the given data sets or the importance of the context. All these interactions might direct the teacher’s focus on students’ mathematical thinking deeply as consistent with the study of Fernandez et al. (2020). In other words, the collaboration among the teachers and the facilitator throughout the discussion might allow the teacher to attend the details of the given strategies and interpret students’ understanding by covering all the essential concepts such as variability and representativeness. Moreover, the teachers were provided with two students’ strategies, and the way the S2 solved the problem was particularly challenging and unfamiliar for the teachers. This might lead to a productive discussion with an increased collaboration among teachers.

Another factor contributing to the development in the teacher’s noticing skills could be the asynchronous nature of the OPD. Clay et al. (2012) argues this mode of communication slows down the process of learning, which could enable teachers to spend more time to consider and revise their ideas (Fernandez et al., 2012; Klein et al., 2017). Indeed, this was shown by Asli’s one of the statements during the interview held after the discussions in the OPD: “Discussions in the OPD enabled us to think more closely on the students’ answers.” Thus, asynchronous modes of communication provided via the OPD might play an effective role in developing the teacher’s attention to the given task, leading fruitful communication among teachers, which in turn enhances her noticing skills.

Although there was clear improvement in attending and interpreting skills of the teacher, deciding how to respond based on students’ understandings was more difficult for her as well as other teachers. Prior to the discussion, the teacher’s questions seemed to be directing students to the correct answer, which was also observed by Klein et al. (2017). Even though the teacher suggested asking probing questions to challenge students throughout the discussion, she had difficulty in extending students’ understanding to a further point after the discussions. Although some new ideas were presented by the facilitator during the synchronous session, such as the use of graphical representations of the data presented in the basketball problem and the importance of context for interpreting data, these ideas were not reflected in the teacher’s responses during the interview. Therefore, in future research, we suggest carrying such specific ideas into the OPD to provide teachers with a more productive discussion environment for the deciding skill. Moreover, this study did not aim to generalize the

findings observed to other teachers in the OPD, as it is limited to only one teacher as a representative example of a collaborative environment. Thus, we recommend examining the development of other participating teachers' noticing skills within the group discussion held in the OPD. Lastly, it would be good to examine how the teachers' evolving expertise is reflected into her instructional practices in further research studies.

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