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Informal Formative Assessment Conversations in Mathematics: Focusing on Preservice Teachers' Initiation, Response and Follow-up Sequences in the Classroom

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Abstract
This study highlighted the characteristics and patterns of preservice teachers' informal formative assessment conversations woven into mathematics classrooms. Participants were four preservice teachers from an elementary mathematics methods course whose videotaped lessons were analyzed using an analytic framework based on Initiation, Response and Follow-up (IRF) sequences. Findings indicated that the patterns of IRF sequence were varied across the preservice teachers, although they taught the same topic. We also found common patterns in their IRF sequences in that preservice teachers mainly initiated and drove classroom conversations of mathematics, while students' roles were passive. In addition, they used frequent follow-up questions; however, most of them were closed questions intended to guide students to quickly give correct responses. Regarding feedback, their feedback were mostly made to affirm or elaborate on what students said or to clarify meanings of statements, not to explore students' initial ideas or reasoning processes.

Keywords: assessment conversation, informal formative assessment, mathematics, preservice teacher education

INTRODUCTION

Formative assessment is defined as an assessment activity that provides information about student learning to be used by teachers and by students' peers as feedback and to modify teaching and learning activities (Black, Harrison, Lee, Marshall, & Wiliam, 2002). Formative assessment is often considered as formal assessment practices or techniques that are explicitly tied to a purpose for gathering information about students' thinking and learning. Many resources for formative assessment techniques or strategies are available to be integrated into existing curriculum materials. However, formative assessment can be another form of informal classroom practice. Sezen-Barrie and Kelly (2017) mentioned that formal formative assessments that are preplanned, scored, or recorded are helpful to understand students' progress in learning; however they are limited in gathering information about dynamic social construction of knowledge and students' reasoning and argumentation skills. Because classroom activities naturally involve interactions between teacher and students and between students, a great deal of information about student learning is collected through classroom conversations (Ruiz-Primo, 2011). Duschl and Gitomer (1997) called these classroom conversations—especially those facilitated and mediated by the teacher to elicit students' thinking and to provide feedback and respond to their thinking—assessment conversations. Assessment conversations are routinely embedded in classroom teaching and occur spontaneously and informally. Sezen-Barrie and Kelly (2017) also emphasized the importance of informal formative assessment as a form of classroom conversations. Informal formative assessments integrated into ordinary instructional activities can be used by teachers to glean information about student learning each time students participate in classroom conversations (Sezen-Barrie & Kelly, 2017). Many studies also support conversational interaction-based informal formative assessments in supporting students' learning, and suggest that questioning is the most common strategy to engage

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Contribution to the literature

- Preservice teachers often used closed follow-up questions to quickly guide students to correct answers.
- Students' role contributing to the classroom conversations was at best passive in that they were asked to provide simple, direct answers to questions and had limited opportunities to initiate a new question or to question teachers' or their peers' statements.
- Preservice teacher education programs should emphasize how to help preservice teachers develop informal formative assessment conversation practices that foster mathematical communication.

students in the process (Chin, 2006; Cobb, Boufi, McClain, & Whitenack, 1997).

During an informal formative assessment such as an interactive classroom conversation, teachers explore students' ideas and use questions to scaffold students' thinking to help them construct normative knowledge (Chin, 2006). Previous studies focused not only on teacher initiations of classroom conversations but also students' responses and teachers' feedback (e.g., Li, Cao, & Mok, 2016; Mortimer & Scott, 2003). The most well-known sequential patterns in classroom conversation are Initiation, Response and Follow-up (IRF; Sinclair & Coulthard, 1975) and Initiation, Response and Evaluation (IRE; Mehan, 1979). Chin (2007) supported the iterative process of IRF in the classroom as a vital role in diagnosing students' ideas and scaffolding their thinking. Kyriacou and Issitt (2007) reviewed 15 studies with respect to effective teaching and learning in mathematics, and found that mathematics lessons were dominated by traditional IRF sequences. Further, they suggested that the quality of discourse in mathematics classrooms should be enhanced in order to promote students' conceptual understanding. Specifically, they recommended that teachers need to ask open-ended questions and follow-up questions more often to scaffold students' thinking and understanding.

In teacher education, formative assessment is emphasized as an important strategy to teach students; however, informal formative assessments might not be illuminated in teacher education programs. This study explores to what extent informal formative assessment as a form of classroom conversation occurs in preservice teachers' (PSTs) classrooms, in order to provide insight to teacher educators regarding PSTs' informal formative assessment practices. Teachers' instruction may continuously adapt to meet student learning goals during their lessons when teachers' informal formative assessment practices are enhanced (Furtak & Ruiz-Primo, 2007). Thus, we expect that this paper will shed light on the importance of informal formative assessment practices to help PSTs become more adaptive and effective to facilitate students' learning in their classrooms by identifying patterns and characteristics of their informal formative assessment practices.

Research Purpose and Questions

Specifically, this paper explores PSTs' informal formative assessment practices in the classroom to respond to the following questions: To what extent do PSTs demonstrate their informal formative assessment practices as a form of assessment conversation when they are interacting with students? How do PSTs use feedback and follow-up questions as part of informal formative assessment to help students' learning?

Informal Formative Assessment and Assessment Conversations

In constructivist-based classrooms, a teacher's role has been emphasized as that of a facilitator to elicit students' thinking and to construct their conceptual knowledge. Consequently, in those classrooms, teachers ask questions to elicit students' thinking explicitly so that their thinking can be scaffolded as an object of constructive learning (Chin, 2006; Ruiz-Primo, 2011). In order to do so, teachers should be able to adjust their questioning to meet students' needs; therefore, in formative assessment conversations, providing feedback and follow-up to students' responses would be more important than evaluating their responses. Chin (2006) developed a framework to analyze questioning-based classroom conversations based on the IRF sequence (Sinclair & Coulthart, 1975) and found positive effects of F(Feedback)-moves on students' constructing knowledge.

Teacher feedback plays a significant role in classroom conversations. Hattie and Timperley (2007) pointed out that "a critical aspect of feedback is the information given to students and their teachers about the attainment of learning goals related to the task or performance" (p. 88). They suggested four levels of feedback: (1) feedback about the task (FT), (2) feedback about the processing of the task (FP), (3) feedback about self-regulation (FR), and (4) feedback about the self as a person (FS). In particular, Hattie and Timperley (2007) argued that "FS is the least effective, FR and FP are powerful in terms of deep processing and mastery of tasks, and FT is powerful when the task information subsequently is useful for improving strategy processing or enhancing self-regulation" (pp. 90-91). In sum, they emphasized that effective feedback is "clear, purposeful, meaningful and compatible with students' prior knowledge and to provide logical connections" (p. 104). Shute (2008) reviewed the literature on formative feedback, and asserted that in order to be effective, feedback should address the accuracy of a student's response to a question or task. To effectively assess the accuracy of students' responses or performance, teachers should have the skills and knowledge to evaluate and describe the quality of the work (Ruiz-Primo, 2011; Sadler, 1989). As such, it is necessary to provide opportunities for PSTs to possess those qualities to provide appropriate feedback for students' work or performance.

Teachers' questioning is also an important attribute for an effective informal formative assessment. Jiang (2014) pointed out that not all questioning can be an assessment tool. For example, when questioning is used to develop students' interests in the teaching topic rather than examine their learning, or follow-up actions are not taken to facilitate their learning, it cannot lead an assessment conversation nor be labeled as informal formative assessment (Jiang, 2014). Questions to facilitate students constructing knowledge should be open-ended and usually require one- or two-sentence answers (Baird & Northfield, 1992). Chin (2007) described the role of teachers' questions as "the rungs of a cognitive ladder" (p. 837) that help students ascend to higher levels of thinking and knowledge. Also, teachers' subsequent questions as follow-up to students' responses to an original question should be effective to engage them in higher-order thinking, self-evaluating, and reflecting on their own thinking (Chin, 2006). In sum, teachers' questioning, feedback, and follow-up questions together can effectively facilitate students developing their responses and thinking at an ascending order of cognitive levels (Chin, 2006, 2007).

Formative Assessment Practice in Mathematics Classrooms

Formative assessment practice has been recognized and emphasized by several professional communities in mathematics education (Association of Mathematics Teacher Educators, 2017; Council of Chief State School Officers & National Governors Association, 2010; National Council of Teachers of Mathematics, 2014). For example, NCTM's *Principles to Actions* suggest using evidence of student thinking to assess progress toward mathematical understanding and to adjust instruction continually, as one of the eight core teaching practices for developing mathematical understanding and self-confidence in all students (NCTM, 2014). Accordingly, AMTE's *Standards for Preparing Teachers for Mathematics* emphasize that teachers must understand "how to assess the understandings and competencies of their students and use this knowledge to plan and modify instruction using research-based instructional strategies" (AMTE, 2017, p. 7).

In mathematics classrooms, one of the most effective tools for teachers to assess student prior knowledge and mathematical understanding is using purposeful questions during conversations with students. In other words, teachers should pose questions purposefully not only to *assess* student thinking but also to *advance* their reasoning and sense making about important mathematical ideas and relationships (NCTM, 2014). Previous studies have investigated in-service and PSTs' practices of using questions in the context of mathematics teaching and learning by employing various methods such as observing mathematics lessons (Franke et al., 2009; Sahin & Kulm, 2008) or engaging teachers in formative interviews with students (Moyer & Milewiz, 2002; Sleep & Boerst, 2012; Weiland, Hudson, & Amador, 2014). Findings showed that the majority of teachers focused on lower-level or factual questions rather than higher-level or probing questions (e.g., Kawanaka & Stigler, 1999; Moyer & Milewiz, 2002; Sahin & Kulm, 2008; Weiland et al., 2013), which was consistent with previous studies on teacher questioning in general (Myhill & Dunkin, 2005; Wilen,1991). For example, Sahin and Kulm (2008) investigated types of teacher questions in two sixth-grade teachers' videotaped math lessons and found that the majority of questions were factual questions. They also found that the teachers used similar types of questions over different stages of lessons, meaning that there was no clear questioning pattern found as teaching and learning activities were changed in a lesson. In another study, Moyer and Milewiz (2002) interviewed 48 elementary PSTs individually to investigate their questioning skills and found that they often asked questions to guide the students to correct answers or to prompt them to single answers, but those questions did not lead to deeply probing for student mathematical thinking. Weiland et al. (2013) also examined one pair of elementary PSTs' formative assessment practice in the context of a teaching methods course and its associated field experience. Their findings showed that the PSTs used unspecific follow-up questions, at best, by providing direct hints or cues that could not refine or explore students' mathematical reasoning. Studies have found that not only PSTs but also in-service teachers demonstrate a lack of ability to use quality questioning skills (Franke, 2009; Ong et al., 2010; Sahin & Kulm, 2008). For example, Ong et al. (2010) found that experienced mathematics teachers often asked questions to probe or guide students to a single answer.

In summary, previous studies found that teachers' questions in mathematics classrooms mostly focused on checking student factual knowledge, which does not lead to extending and deepening their mathematics ideas (Ong et al., 2010; Sahin & Kulm; Sleep & Boerst, 2012). Furthermore, teachers found it difficult to follow up on student explanations or probe students' thinking in ways that could support students to elaborate on their strategies or extend their ideas (Franke, Fennema, Carpenter, Ansell, & Behrend, 1998; Moyer & Milewicz, 2002). This could possibly be due to the lack of support and scaffolding for teachers to develop their questioning skills (Sleep & Boerst, 2012), or to their lack of content knowledge in mathematics (Kreide, 2015; Ong et al., 2010).

In the current study, we specifically focused on PSTs' informal formative assessment practice when teaching fractions. Fractions is an important topic in elementary mathematics, as it is essential for future learning of algebra, geometry, and other topics of higher mathematics, but at the same time, it is a difficult topic for students to learn and for teachers to teach (Fazio & Siegler, 2011; Lamon, 2007; Newton 2008, Van Steenbrugge et al., 2010; Zhou, Pevery, & Xin, 2006). The major difficulty for students in learning fractions is the interference with their prior knowledge about whole numbers, which produces various misconceptions (English & Halford, 1995; Ni & Zhou, 2005; Stafylidou & Vosniadou, 2004). In an effort to improve teachers' practice that supports students' learning of fractions, several studies have been done with in-service teachers (e.g., Cai & Wang, 2006; Isiksal & Cakiroglu, 2011, Izsak, 2008). However, research on PSTs' informal formative assessment practice in actual teaching contexts is relatively rare. Also, previous studies generally focused on teacher questioning without taking into account conversational interactions between the students and the teacher. In this study, we examined PSTs' informal formative assessment conversations using the IRF process (Sinclair & Coulthard, 1975) as an analytic approach to capture characteristics and patterns of their informal formative assessment conversations. Specifically, we considered R- and F-moves as an iterative process in the IRF sequence. In other words, after students responded (R-move) to an initiated question (I), the teacher provided feedback or follow-up questions (F-move) based on the responses, and students would answer the subsequent questions (R-move), and so on (Scott & Mortimer, 2005). Thus, as the nature of assessment conversation (Furtak & Ruiz-Primo, 2007) the IRF sequence can have more than one iteration of the cycles of R- and F-moves to reach a desired learning outcome.

METHODS

Context

Participant PSTs were drawn from an elementary mathematics methods course for Grades 1 through 5 at a large research university in southwestern US. This course implemented four 3-week modules, each focused on major mathematics topics in the state level elementary mathematics curriculum standards, i.e., numbers and operations with whole numbers, numbers and operations with fractions, algebra, and geometry and measurement (Texas Education Agency, 2013). Fractions are a major topic in elementary school and span across multiple grade levels. For example, numbers and operations with fractions is first introduced in second-grade where students use concrete models to partition objects into equal parts and name parts as halves, fourths, and eighths, count fractional parts beyond one whole using words, and are expected to explain the relationship between the number of fractional parts in a whole relative to the size of those parts. In third grade, fractions expand to include thirds and sixths, and children are expected to explain that a unit fraction 1/b represents the quantity formed by one part of a whole that has been partitioned into b equal sized parts. Fourth graders are expected to represent a fraction a/b as a sum of unit fractions 1/b, decompose a fraction into a sum of fractions with the same denominators using concrete and pictorial models, compare two fractions with different numerators and different denominators, and add or subtract fractions with equal denominators using objects and pictorial models. Moving up to the fifth grade, students are expected to represent and solve addition and subtraction of fractions with unequal denominators, multiplication of a whole number and a fraction, and division of a unit fraction by a whole number and the division of a whole number by a unit fractions using objects and pictorial models (Texas Education Agency, 2013). Due to the complexity of fraction topics and student struggles with fractions, this topic was chosen as it would provide many opportunities for PSTs to confront unexpected students responses and to interact with them verbally when teaching as a form of informal formative assessment of their learning.

When PSTs were taking the 3-week module for the topic, they first learned about the meaning of fractions and how to teach fractions and operations. They then engaged in classroom discussions with their peers and instructors about how to teach fractions and operations with fractions. They also engaged in group discussions about teaching videos where expert teachers modeled mathematics methods for teaching fractions and operations. Then the course instructor demonstrated and elaborated on some examples of students' misunderstandings about various aspects of fractions (Bamberger, Oberdorf, Schultz-Ferrell, & Leinwand, 2011) and engaged PSTs to analyze these examples and come up with approaches to address the misunderstandings shown. Finally, each group shared the outcomes of their group discussions with the class.

While PSTs were taking the course, they were placed in elementary or middle schools to practice their teaching. In order to provide an opportunity for PSTs to connect what they had learned from the course with their actual teaching practice, they were asked to choose a mathematical problem related to the topic and teach a mini-lesson to students in their placements.

Table 1. Participant Demographics and Their Chosen Classwork Problems

	Amy	Maria	Rosita	Jose
Gender	Female	Female	Female	Male
Age	18-24 years	45-54 years	25-34 years	18-24 years
Ethnicity	Hispanic/Latinx			
Classroom	5th grade math class			
Classwork Problem	Two fractions add up to 1/2. What might those two fractions be?			What three fractions might I add together and get an answer of 1/2?
Learning objectives (TEKS))	5.3H: the student is expected to represent and solve addition and subtraction of fractions with unequal denominators referring to the same whole using objects and pictorial models and properties of operations.			5.3K: The student is expected to add and subtract positive rational numbers fluently.

Note: Names are all pseudonyms

Data Sources

A requirement of the elementary mathematics methods course from which participants were drawn was that they video-record a lesson aligned with course topics taught in the course to students in their associated math classroom field placements. Thus, we used the videotaped lessons as the primary source of data. PSTs were provided equipment to record the lessons they taught on a mathematical topic covered in the methods course and implemented one open-ended problem associated with the topic of fractions. For this study, chosen participant PSTs posed the same or similar open-ended problem to children in their placement classrooms. This problem asked students to find two (or three) fractions whose sum is ½. This problem has multiple solutions and strategies that can be used to solve. For example, using their knowledge of equivalent fractions and how to compose and decompose fractions, a student could have systematically began by first finding fractions equivalent to ½ (e.g., 2/4, 3/6, 4/8) and then decomposed those fractions into the sum of two fractions (e.g., 2/4=1/4 +1/4, 3/6=1/6 +2/6 or 1/6 + 1/6 + 1/6, 4/8=1/8 + 3/8 or 2/8 + 2/8 or 1/8 + 1/8 + 1/8). Alternatively, a student could have used the guess and check strategy to find possible solutions. Furthermore, solutions could have been found by using concrete models (i.e., fraction tiles, fraction circles), drawings, or symbolic representations.

We selected videos for the study using the following criteria: the lesson (1) focused on teacher-led classroom conversation, (2) focused on the topic of fractions and operations and (3) implemented the same or a similar open-ended question related to the topic. We found four PSTs' videos that met the criteria. The four PSTs reported themselves as Hispanic or Latinx, reflecting the increasing number of Hispanic/Latinx teachers in the southwestern United States (Taie, Goldring, & Spiegelman, 2017). Their placements were in schools where Hispanic students were the majority (over 80%). Table 1 presents information about the PSTs and the classwork problems that they chose to teach for their mini-lessons.

Analytical Framework

The first author developed an analytical framework (Table 2) based on the IRF sequence analysis framework (Chin, 2006; Sinclair & Coulthard, 1975) and Hattie and Timperley's (2007) feedback models to analyze teacher informal formative assessment conversations. To be more specific, the original R-move and F-move were further divided, i.e., R-without Q move and R-Q move, F-without Q move and F-Q move, to identify different patterns in the conversation. I-move was coded only when a person (a teacher or a student) initiated a question addressing a new topic, and F-Q was coded when a teacher asked a question as follow-up or feedback but the question did not address a different topic from the initial question. R-Q was coded when a student asked a question as a response to the teacher's question. I-move was then coded if it was an open-ended or a closed question. F-without Q and F-Q moves were also coded using F-move descriptions (Table 2) to characterize their purpose; e.g., to affirm students' response or to elaborate on their answers.

Two authors coded a whole transcript of one PST's video using an initial framework while watching the video. Then the two coders compared their coding results, discussed them, and revised codes or reviewed the video when any discrepancy occurred. After the iterative process, the analytical framework was finalized (Table 2). Using the finalized framework, the video was coded again by two coders. The intercoder reliability (Cohen's Kappa) was calculated by category, and found their coefficients were 0.818 (category: Move types), 0.857 (category: I-move question types) and 0.725 (category: F-move descriptions) ($p < .05$). The average intercoder reliability coefficient across three categories was 0.800. After that, one coder coded the other three videos. We note that we divided the video and transcripts whenever an instructional activity was changed, and regarded the segments of video as episodes. Among the episodes, we analyzed when each episode involved informal formative assessment conversations between teacher and students. If we did not detect a moment of informal formative assessment conversations in an episode, (e.g., students were

Table 2. Analytical Framework for Informal Formative Assessment Conversations

Category	Code	Description
Move types	I	Initiation
	R-without Q	Student response without asking a question
	R-Q	Student response as a question
	F-without Q	Feedback/Follow-up without asking a question
	F-Q	Follow-up questions to guide students to answer to the initiated question
I-move question types	Closed question	Closed question (e.g., single correct answer, Yes/No answer)
	Open-ended question	Open-ended question (e.g., explanation/reason/justify)
F-move descriptions	Affirmation	Repeat/paraphrase students' words, tell if their answer is correct, or ask them again to affirm their answer
	Praise	Simple praise about task
	Correction	Tell students correct answers
	Criticism	Tell students their answer is incorrect
	Clarification/Elaboration (based on responses)	Clarify what it (questions/tasks/content) means/Elaborate on student answers with further exposition
	Peer review/Compare/Contrast students' ideas	Students review peers' tasks or answers/Provide an opportunity to compare or contrast different ideas
	Checking	Check if students are doing what they are supposed to do, or tell them what to do
	Refining/Breaking down questions	Change words or phrases of a question to help students answer/Break down questions to provide cues

Table 3. Raw and Relative Frequencies of IRF Sequence and Components

		Raw Frequency (Relative Frequency)			
		Amy	Maria	Rosita	Jose
	Number of episodes	16	10	10	5
I-Move	I-move total	13 (100%) [a]	10 (100%)	8 (100%) [b]	5 (100%)
I-Move Question Types	Closed Q	7 (54%)	6 (60%)	4 (50%)	3 (60%)
	Open-ended Q	6 (46%)	4 (40%)	4 (50%)	2 (40%)
R-Move	R-move total	74 (100%)	54 (100%)	66 (100%)	57 (100%)
	R-without Q	68 (92%) - 7 for Yes/No response	44 (82%) -9 for Yes/No response	63 (95%) -24 for Yes/No response	48 (84%) -16 for Yes/No response
R-Move Types	R-Q	6 (8%)	10 (19%)	3(5%)	9 (16%)
F-Move	F-move total	65 (100%)	55 (100%)	60 (100%)	58 (100%)
	F-without Q	25 (38%)	22 (40%)	17 (28%)	11 (19%)
F- Move Types	F-Q	40 (62%)	33 (60%)	43 (72%)	47 (81%)
	Closed	33	26	39	39
	Open	7	7	4	8

Note. [a] 2 cases were initiated by students. [b] 1 case was initiated by a student

individually working on tasks), we excluded the episode from the analysis.

RESULTS

This section presents analysis results of utterances between the PST and students focused on the IRF sequence and its components. We present the raw and relative frequencies of the IRF sequences and components, then compare those descriptive statistics to identify commonalities and differences across the four PSTs' informal formative assessment conversations.

Raw and Relative Frequencies of IRF Sequence and Components

Descriptive statistics for the IRF sequences and components in four PSTs' classrooms are presented in Tables 3 and 4. Table 3 shows that PSTs' informal formative assessment practices varied considerably. We note that the total number of I-moves indicates the number of IRF sequential conversations. For example, while we identified 16 episodes in Amy's classroom, 13 episodes involved IRF sequences, meaning that the other three episodes did not involve IRF sequences. Although the four PSTs selected the same or similar topics to teach, we found different patterns in IRF sequences. For instance, Amy's lesson involved 1.62 times as many I-moves as Rosita's lesson (eight IRF sequences); however, the differences in the total number of R-moves and the total number of F-moves between two PSTs were not as big as the difference in the total number of I-moves; Amy's lesson involved 1.10 times as many R-moves and 1.04 times as many F-moves as Rosita's lesson. As another example, Maria's lesson involved 10 I-moves and Jose's lesson only included five I-moves; however, the numbers of R- and F-moves in Jose's lesson were

Table 4. Raw Frequencies of F-Move Descriptions

	Raw Frequency (Relative Frequency)				
	Amy	Maria	Rosita	Jose	Total
F-without Q					
• Affirmation	6 (19%)	13 (29%)	5 (29%)	7 (39%)	31 (28%)
• Praise	3 (10%)	8 (18%)	0 (0%)	0 (0%)	11 (10%)
• Correction	2 (6%)	4 (9%)	5 (29%)	4 (22%)	15 (14%)
• Criticism	3 (10%)	5 (11%)	1 (6%)	1 (6%)	10 (9%)
• Clarification/Elaboration	12 (39%)	11(24%)	6 (35%)	6 (33%)	35 (32%)
• Peer review/ Compare/Contrast students' ideas	0 (0%)	1 (2%)	0 (0%)	0 (0%)	1 (1%)
• Checking	4 (13%)	1 (2%)	0 (0%)	0 (0%)	5 (5%)
• Refining/ Breaking down questions	1 (3%)	2 (4%)	0 (0%)	0 (0%)	3 (3%)
Total*	31 (100%)	45 (100%)	17 (100%)	18 (100%)	111 (100%)
F-Q					
• Affirmation	8 (15%)	5 (11%)	5 (8%)	21 (26%)	39 (16%)
• Praise	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
• Correction	2 (4%)	1 (2%)	0 (0%)	3 (3%)	6 (2%)
• Criticism	2 (4%)	1 (2%)	4 (6%)	0 (0%)	7 (3%)
• Clarification/Elaboration	10 (19%)	6 (14%)	13 (20%)	19 (24%)	48 (20%)
• Peer review/ Compare/Contrast students' ideas	3 (6%)	1 (2%)	1 (2%)	2 (3%)	7 (3%)
• Checking	22 (42%)	15 (34%)	15 (23%)	13 (16%)	65 (27%)
• Refining/Breaking down questions	6 (11%)	15 (34%)	28 (42%)	22 (28%)	71 (29%)
Total	53 (100%)	44 (100%)	66 (100%)	80 (100%)	243 (100%)

Note. The total numbers are different from those in Table 3 because a PST's feedback utterance can be classified into multiple feedback description categories.

greater than in Maria's, which implied that Jose's lesson might be more interactive between the PST and students. On average, in Amy's case, one IRF sequence contained six R-moves (74 total R-moves/13 total I-moves) and five F-moves (65 total F-moves/13 total I-moves); in Maria's case, one IRF sequence contained five R-moves (54 total R-moves/10 total I-moves) and six F-moves (55 total F-moves/10 total I-moves); in Rosita's case, one IRF sequence involved eight R-moves (67 total R-moves/8 total I-moves) and eight F-moves (62 total F-moves/8 total I-moves); and in Jose's case, one IRF sequence had 11 R-moves (57 total R-moves/5 I-moves) and 12 F-moves (58 total F-moves/5 I-moves). This result indicated that the patterns of IRF sequence were varied across PSTs even though they taught the same topic. For example, on average Jose and Rosita provided more frequent feedback/follow-up within an IRF sequence.

Table 3 also showed that PSTs used both open-ended and closed questions to initiate assessment conversations (i.e., I-move). Regarding F-moves, all PSTs provided F-Q types of F-move more often than F-moves without a follow-up question (F-without Q). However, when they provided F-Q moves, closed questions were dominant compared to open-ended questions as follow-up questions, which implies that the PSTs provided F-Qs to quickly guide students to correct answers, not to explore or provide an opportunity for students to express their own ideas or misconceptions. Regarding students' responses (R-move), the total number of R moves was from 54 to 74. We further divided the R-moves into *R-without Q* and *R-Q*. R-without Q was coded when a student responded to the PST's I-move or F-move without asking a question (R-without Q). Whereas, when a student responded to the PST's moves by asking a question, we coded the utterance with R-Q. It was noticeable that, among those R-without Q moves, yes/no responses were frequently found in Rosita's and Jose's classrooms (24 times for Rosita's class and 16 times for Jose's class), as they asked many closed follow-up questions (e.g., "Agree?" or "Do you have this?"); 39 times closed F-Q moves were found in both Rosita's and Jose's class. Thus, frequent yes or no responses were not surprising.

It is possible that students may ask questions to clarify or expand on what teachers have asked, but this type of response (R-Q move) was not often observed. The low frequencies of R-Q moves and students' I-moves indicated one directional interaction, from teacher to students, occurred in PSTs' classrooms. Specifically, the number of R-Q moves was smaller than the number of R-without Q moves, while teachers' F-Q moves happened more often than their F-without Q moves. Also, students' I-moves were rarely detected (only two I-moves by students were found in Amy's class and one I-move by a student was found in Rosita's class), which indicated that opportunities to use students' own ideas as resources for informal formative assessments were limited in the PSTs' classrooms. In summary, to initiate informal assessment conversations, the PSTs used both open-ended and closed questions, but once they initiated the conversations, they used closed questions as follow-up questions to quickly guide students to correct answers rather than to explore their initial ideas.

Next, we classified PSTs' feedback utterances (F-moves) into eight feedback/follow-up descriptions. For example, when a student responded (e.g., answered "Four") to a PST's question, the PST said "Yes, it is four! It's as many parts as I'm cutting this cake into." The feedback/follow-up utterance was classified into two descriptions: "Affirmation—*Yes, it is four!*" and "Elaboration—*It's as many parts as I'm cutting this cake into.*" After completing the categorizations of their F-moves, we found variations between PSTs' types of feedback description.

First, Affirmation and Clarification/Elaboration (based on response) were dominant in F-without Q moves. In F-Q moves, although Affirmation and Clarification/Elaboration (based on response) feedbacks were often observed, Checking and Refining/Breaking down questions were more frequently observed.

Second, it was found to be common that PSTs provided F-Q moves more often than F-without Q moves. However, depending on the PSTs, there were differences in frequency between the two types of feedback moves (i.e., F-without Q moves and F-Q moves). Amy provided the most frequent Checking F-Q moves (22 times) among the four PSTs, while the frequency of Refining/Breaking down questions F-Q moves was the least (6 times) among them. In contrast, Rosita and Jose provided more Refining/Breaking down questions F-Q moves than Checking F-Q moves. Also, they provided more frequent F-Q moves than F-without Q moves (almost twice as many F-Q moves than F-without Q moves), implying that they continuously interacted with students by trying to engage them in the conversation. In the case of Maria, she provided the least frequent feedback moves to students among the PSTs, and the frequency difference between F-without Q moves and F-Q moves was the smallest. Notably, most of the PSTs' follow-up questions were at best asking to clarify/elaborate on or to check what students were doing, or to ascertain if they were working as they were supposed to. Refining/Breaking down questions were also found often; however, these were mostly to quickly guide students to correct answers, not to explore their initial ideas or reasoning processes. Therefore, students' contributions to the classroom discourses were limited in that their roles were mostly providing simple answers directly to questions, while they had a limited opportunity to initiate a new question or to question teachers' feedback.

Third, Peer review/Compare/Contrast students' ideas cases were observed the least in total F-moves. Peer review/Compare/Contrast students' ideas could provide students an opportunity to reflect on their own ideas, to get involved in argumentation, and to expand their initial thoughts with support from teacher feedback. The PSTs demonstrated their feedback practices without providing counterparts that could be contradicted or compared with students' original ideas, which implies their lack of practice in using constructive feedback. Rather, they adopted the use of feedback to correct students' responses or to quickly guide them to give desired responses (a single correct answer). Also, the Refining/Breaking down questions could be used to scaffold students' reasoning; however, in most cases the feedback at best changed the wording of the initial question or made the question easier to understand in order to provide cues for students to answer.

Example Cases of Using Closed or Open-Ended Follow-up Questions

In the previous section, we presented raw and relative frequencies of IRF sequences and their components observed in PSTs' classrooms, and found that most PSTs' feedback was direct instructional feedback to quickly guide students to the correct answers, while constructive feedback exploring students' ideas and allowing them to compare/contrast different ideas was limited. Although the raw and relative frequencies of IRF sequences and components were useful to show which IRF moves were often or rarely observed in PSTs' classrooms and enabled us to compare their classroom conversations directly, they do not show how PSTs' feedback and follow-ups were associated with students' responses and what types of follow-up questions were offered to students. In this section, we explore the type of PSTs' feedback and follow-up questions, and how they were related to students' responses. Specifically, we focus on cases of using open-ended or closed follow-up questions to facilitate students' learning.

Table 5 presents an IRF sequence in Amy's classroom. She started with an open-ended question to initiate an informal formative assessment conversation, which was to assess if students were able to find two fractions that would make one half when they were added together. Using a student (S1)'s first response, she used a closed follow-up question to guide two students (S1 and S2) to answer that adding the two fractions was equivalent to one half. When S1 mentioned that 3/12 plus 3/12 equals 6/12, Amy asked, "Which is the same as?" so that S1 would give the desired answer. Then Amy used S1's answer to help S2 find the correct answer without asking S2 to express her/his original idea. In summary, Amy used closed questions to clarify or provide direct cues for students to answer; however those questions were not used to elicit students' original thinking or to lead their thinking explicitly.

The second example (Table 6) shows a case in which a PST (Rosita) used open-ended follow-up questions along with closed ones. In the episode, Rosita asked students to find two fractions that add up to one half, and she checked each student's process for the task by using open-ended questions (e.g., "What did you write?" and "What did you want to do for it to solve your problem?"). She also asked closed follow-up questions to guide students to correct answers by clarifying what the task was asking (e.g., "We're trying to find two fractions right, that makes a half.") or asking to elaborate on the student's work (e.g., "So S1 so you said that you

Table 5. Example of Using Closed Follow-Up Questions (Amy's Case)

Speaker	Transcript	I-move	R-move	F-move	F-move description
T(eacher)	So now I want you to think of this: I want you to find two fractions that we can add together but equal one half. ...Two fractions!	Open-ended			
S(tudent) 1	Three twelfths plus three twelfths [3/12 + 3/12].		R-without Q		
T	Let's…show me with your model [using tiles].			F-without Q	Checking
S1	Three twelfths plus three twelfths.		R-without Q		
T	Oh! Look at that!			F-without Q	Praise
S1	Equal six... [inaudible, probably "twelfths"]		R-without Q		
T	Which is the same as?			F-Q Closed Q	Refining/Breaking down questions
S1	One half.		R-without Q		
S2	You said three fractions that add up...?		R-Q		
T	Two fractions!			F-without Q	Correction
S2	Three sixths, three sixths…		R-without Q		
T	You probably found an equivalent fraction, but I need to find two different fractions. For example, S1 said this 3/12 plus 3/12 and he said that equals what?			F-Q Closed Q	Clarification/Elaboration based on responses Affirmation
S1	One half.		R-without Q		
T	One half! But because these two equal 6/12.			F-without Q	Affirmation, Clarification/ Elaboration based on responses

Table 6. Example of Using Open-Ended Follow-Up Question (Rosita's Case)

Speaker	Transcript	I-move	R-move	F-move	F-move description
T	Okay so you guys were supposed to what, find two fractions that add up to 1/2 right? What did you write?	Open-ended question			
S1	I wrote 2/8 plus 2/8 equal 4/8 and then half of 4/8 equal 2/4 so half of 2/4 equal a half.		R-without Q		
T	[T showing fraction circles and a fraction strip to students] Okay okay so here we have fraction circles right, this represents a whole, and we have a fraction strip and this represents a whole, so S1 so you said that you use 2/8 right?			F-Q Closed question	Clarification/ Elaboration based on response
S1	Uh-uum.		R-without Q		
T	Oh, and we're trying to add two fractions right, that makes a half. So you use 2/8 plus... yes I'm sharing with you. These are kind of difficult to find. So, 2/8 that's it. Do we see that 2/8 does equal a half here?			F-Q Closed question	Clarification/Elaboration based on response Refining/Breaking down question
SS (students)	Yes.		R-without Q		
T	Okay, so S2, what did you want to do for it to solve your problem?			F-Q Open-ended question	Checking
S2	I took everything. I had 1/6 and 1/4… [inaudible]		R-without Q		
T	Okay so let's look at S2. So, she's trying to get to half, she wrote right 1/6 and 1/2? Oh 1/4? 1/4 and 1/6, so was S2 correct?			F-Q Closed question	Peer review/ Compare/Contrast
S3	Um, no.		R-without Q		
T	So, right. So what could she have done differently?			F-Q Open-ended question	Refining/Breaking down question
S4	1/8 plus.		R-without Q		
S1	No cause 1/8, look would be smaller.		R-without Q		
S4	Ohh, yes. Yes.		R-without Q		
T	This is 1/12 but we need two fractions. This is 3 [fractions]. So what could we possibly replace the 1/6 and the 1/12 for to give us 1/2?			F-Q Closed question	Correction. Refining/Breaking down question
SS	1/4.		R-without Q		
T	Hah, so 1/4 so 1/4. So does that equal half?			F-Q Closed question	Affirmation, Checking
SS	Yes!		R-without Q		

use 2/8, right?"). Those types of F-Qs (i.e., Checking and Clarification/Elaboration) were commonly found from the participant PSTs. Notably, Rosita asked closed follow-up questions asking students to provide peer reviews about another student's process (e.g., "She's trying to get to half, she wrote 1/6 and 1/2? Oh 1/4? 1/4 and 1/6, so was S2 correct?"). Then she asked students to revise the incorrect process (e.g., "So what could we possibly replace the 1/6 and the 1/12 for to give us 1/2?"). This episode provided an example case in which the teacher used student ideas identified in their class to expand or elaborate on their thinking. We noted that this type of feedback utterance was found rarely, while their follow-up questions were often made to affirm, clarify, or simply check students' ideas. Although Rosita used the follow-up question asking for a peer review, most of her follow-up questions were closed ones that provided direct cues for students to answer correctly, which did not afford them a chance to fully explore others' ideas. Therefore, students' contributions to the classroom discourses were limited in that their roles were mostly providing Yes or No answers, short or one-word responses, and they had limited opportunity to initiate a new question or to question others' statements.

DISCUSSION

In this study, we explored PSTs' informal formative assessment conversations in mathematics class focused on IRF sequences. The analysis results showed that the number of I-moves were different by PSTs even though they selected the same or similar topics for their lessons. A commonality in PTSs' I-moves was that they used both open-ended and closed questions to initiate conversations, and frequencies of using either open-ended or closed questions were similar. Also, PSTs provided frequent feedback with follow-up questions (ranging from 33 to 47 F-Q moves in total). This finding does not necessarily mean that they consistently asked students to explain their thinking or explored students' initial ideas. Rather, PSTs used follow-up questions to quickly guide students to correct answers. In constructivist-based classrooms, teachers are expected to explore students' initial ideas and facilitate their learning through scaffolding or challenging questions; however, we found that closed follow-up questions were more dominant, with PSTs asking for single-word or simple answers from students. Overall, PSTs' feedback was mostly made to affirm students' answers, clarify meanings of statements (or questions), or elaborate on what students said, which aimed to quickly guide students to correct answers rather than to explore their initial ideas or reasoning processes.

We also found that most assessment conversations were initiated and driven by PSTs, while students' initiations of the assessment conversation and their questions as responses (R-Q moves) were limited. Consequently, students' role contributing to the classroom conversations was at best passive in that they were asked to provide simple, direct answers to questions and had limited opportunity to initiate a new question or to question teachers' or their peers' statements. This also indicated that PSTs demonstrated their limited abilities to utilize students' own ideas as resources to initiate or enhance informal formative assessment conversations.

As informal formative assessment conversation examples showed, a PST sometimes followed up with questions to encourage peer reviews, or to compare or contrast students' ideas, but those cases were not often observed. The follow-up questions (peer review/compare/contrast) could have helped students make their thinking explicit and expand their ideas. However, the PSTs mostly used closed questions as follow-ups to quickly lead students' responses, even when they asked students to peer review, compare, or contrast other ideas. Even when they used open-ended follow-up questions, those questions were mostly made to check students' work, not to explore their thinking. Previous studies about IRF sequences in classrooms focused on the frequency of IRF cycles or each component of the IRF sequence, but did not pay attention to the types of F-moves. The current study contributed to the body of literature in that we expanded the IRF sequence with different types of F-moves, which can be used as an analytical framework to analyze classroom discourse. As we presented, PSTs used frequent F-moves by asking questions to students, however, they did not actively use student ideas identified through their informal formative assessment conversations as resources to expand student thinking, which is important to do in a constructivist-based classroom. More specifically, we found that PSTs did not ask students to express their thinking explicitly, but their feedback was mostly direct instructional comments that provided direct cues for students to answer correctly. If PSTs could provide more challenging questions or a chance to apply what students learn to a new situation, it could serve as more constructive feedback. In summary, the common features in PSTs' feedback and follow-up were that they (1) often restated students' answers so that the answers became "common knowledge" (Edwards & Mercer, 1987); (2) frequently provided clarification and checking feedback, which effectively directed students to focus on the given task; and (3) offered much less constructive feedback than direct instructional feedback.

Follow-up questions offer opportunities for students to refine and make explicit their explanations or initial thinking. In order to do so, follow-up questions should be deliberately phrased to reveal student ideas and thinking. Franke et al. (2009) found that follow-up questions did not guarantee further student explanation, especially when asking for a single specific answer. We also found that PSTs often asked leading questions that did not relate to students' initial ideas or thinking but instead quickly directed students to answer correctly. In accordance with Franke et al. (2009), we found that while PSTs asked initial questions to elicit students' ideas, they struggled with how to follow up on the ideas (Franke et al., 2009).

Chin (2006) mentioned that teachers' F-moves were influenced by the nature of students' responses (i.e., correct or incorrect responses); however, this study did not find evidence to support the claim. Rather, we found that PSTs' common assessment conversation type was unidirectional (from teacher to students) and authoritative, allowing students limited opportunities to contribute to the conversation. In constructivist-based classrooms, the emphasis is on giving students the responsibility to reflect and reason through their ideas (van Zee & Minstrell, 1997). Thus, it is important for teacher educators to understand how to help PSTs develop informal formative assessment conversation practices that foster mathematical communication. Findings of this study will inform mathematics teacher educators of PSTs' strengths and weakness in regard to informal formative assessment practices and provide important foundations for designing mathematics methods course instructional activities and assignments to better prepare elementary PSTs for the informal formative assessment practice. Based on the findings, we suggest that teacher educators should pay attention to develop teachers' knowledge and skills to provide constructive F-moves such as peer reviewing, comparing and contrasting students' ideas rather than just a simple praise or clarification. Future studies should be followed in designing teacher education programs to help teachers create constructive follow-up questions and feedback to elicit student thinking explicitly and to connect their ideas to informal formative assessment conversations.

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