EXAMINING TEACHER CANDIDATES' RESPONSES TO ERRORS DURING WHOLE-CLASS DISCUSSIONS THROUGH WRITTEN PERFORMANCE TASKS

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Effectively leading whole-class mathematics discussions is made more difficult when students' contributions are incomplete, imprecise, or not yet correct, and not easily correctable—what we call "errors." Through purposefully designed opportunities to investigate, enact, and reflect on teaching, teacher candidates (TCs) can develop skill to productively respond to errors in whole-class discussions. We investigate how TCs respond to errors when engaging in a written performance task that calls for TCs to play out discussions in response to a classroom scenario. We consider what the performance task reveals about TCs' practice and perspectives, with implications regarding theory and practice.

Keywords: Teacher Education-Preservice, Instructional Activities and Practices

Whole-class mathematics discussions are critical spaces in which students can participate authentically in mathematics and develop a broad set of mathematical proficiencies and practices (Kilpatrick, Swafford, & Findell, 2001). Effectively leading discussions is complex work comprised of eliciting, responding to, and building upon student contributions toward mathematical goals (Boerst, Sleep, Ball, & Bass, 2011). Contributions that are incomplete, imprecise, or not yet correct present an additional challenge for teachers wanting to keep student reasoning central, make progress toward identified goals, and not convey erroneous ideas. We contend that, through purposefully designed opportunities for representing, decomposing, and approximating practice (Grossman et al., 2009), teacher candidates (TCs) can develop skill to productively respond to student errors in whole-class discussions. We share our use of written performance tasks in which TCs produce dialogues and rationales for their dialogues in response to a classroom scenario. Our analyses provide a window into TCs' practice and perspectives and offer implications regarding theory and practice of mathematics teacher education.

Literature Overview

All mathematics teachers have the opportunity to respond to student errors as part of the work of teaching, and there is a robust literature base exploring the role of errors in the mathematics classroom. Understanding teacher responses to student errors requires first defining the term "error." Nesher (1987) argues that making errors are the way in which students contribute to their own learning process. This perspective is echoed in later literature, which emphasizes viewing students as sense-makers and identifying opportunities to build on student thinking (e.g., Van Zoest et al., 2017). Following Brodie (2014), we define errors as incomplete, imprecise, or not yet correct contributions that are more complex than mistakes that are easily correctable. Errors occur "among learners within and across contexts" (Brodie, 2014, p. 223), and move beyond mistakes such as misspeaking or accidently doing an incorrect computation. Taking this view on the role of errors makes it imperative to understand the ways in which teachers respond to errors. One common approach is for teachers to make corrections (e.g., Tulis, 2013), quickly highlighting the error and introducing correct ideas into the discussion. Another approach is to avoid errors (e.g., Bray, 2011; Santagata, 2005) and steer the conversation toward correct contributions. These actions potentially remove the opportunity for students to make

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sense of errors. If students make sense of mathematics at least in part through their errors, then productive teacher responses ought to support that sense-making. Teachers must notice students' mathematical reasoning (Jacobs, Lamb, & Philipp, 2010) and navigate the in-the-moment work of building understanding (Bray, 2011; Leatham, Peterson, Stockero, & Van Zoest, 2015).

An added layer of complexity in responding to errors results from the context in which the error occurs. In whole-class discussions, the teacher must navigate the needs of the student who contributed the error along with the needs of the rest of the class, who may or may not share that student's conception. Leading whole-class discussions requires responding to student reasoning and making student contributions central to the mathematical work of the class (Boerst et al., 2011). In this context, teachers must find ways to navigate making student contributions central at the same time as a desire to have the conversation focus on correct responses. We extend the work on both errors and whole-class discussion in secondary mathematics by considering whole-class discussions as the particular context for responding to errors. We examine the ways in which teachers may respond to errors through analyzing representations of their practice.

Theoretical Framework

We take the perspective that, to develop skilled practice, TCs must not only have opportunities to think about and reflect on teaching using representations of practice such as observation, written vignettes, and video, but also the opportunity to approximate the work (Grossman et al., 2009). This can occur when TCs meaningfully engage in interactive and contingent aspects of teaching in settings of reduced complexity and authenticity. Through opportunities to enact teaching practices in response to student contributions, TCs demonstrate and further develop adaptive skill that coordinates pedagogical approaches, the goals of a particular approach, and a vision of mathematics teaching (Ghousseini, Beasley, & Lord, 2015). These opportunities also provide a lens for teacher educators and researchers to assess TCs' developing practice and their coordination of approaches and goals.

This theoretical perspective frames our use of pedagogies such as coached rehearsals (Lampert et al., 2013), and as teacher educators and researchers we strive to find multiple approximations and strategies for assessing TCs' practice. We use written performance tasks (e..g, Bray, 2011) as an additional way to put TCs in the position to make sense of and respond to student reasoning. In designing these tasks, we draw on research around scripting classroom interactions (Crespo, Oslund, & Parks, 2011; Zazkis, 2017). TCs are presented with a realistic classroom scenario involving whole-class discussion and student errors. TCs demonstrate, through written dialogue, how they might continue the discussion. These dialogues represent, in part, TCs' imagined response to a particular student contribution. They also represent TCs' sense of how students might contribute further, giving insight into TCs' view of what is reasonable or desirable in a classroom episode. TCs also provided a rationale for why they continued the discussion the way they did. In this paper, we explore what these performance tasks say about TCs' developing practice, building on preliminary work (Campbell, Baldinger, Selling, & Graif, 2017). We ask: (1) what are the features of TCs' dialogues written in response to a student error made during a whole-class discussion; (2) what are the features of TCs' rationales for their dialogues written in response to a student error made during a whole-class discussion; and (3) in what ways do TCs' dialogues relate to their rationales, and what do these relationships suggest about TCs' coordination of approaches and goals in their responses to student errors in whole-class discussions?

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Methods

We describe our analyses of one performance task we designed, with a scenario centered on the use of a card sorting activity (Baldinger, Selling, & Virmani, 2016) intended to elicit and refine the following definition of a polygon: “a 2-dimensional (plane) figure, where each side is a straight-line segment that intersects exactly one other side at each endpoint.” In the scenario, the whole-class discussion began after students had worked in small groups. The teacher asked for students to name cards that they easily knew were polygons. One student, Rosalia, offers Shape Q (see Figure 1) and, after a back-and-forth with the teacher, shares that it is a polygon because “it is a square” and that “all the sides are straight lines.” After the teacher asked for another example of a polygon, Jessie offers Shape J (see Figure 1), stating that it was square, like Shape Q. TCs dialogues began following Jessie’s contribution. After writing their dialogues, TCs wrote rationales describing why they continued the discussion as they did.

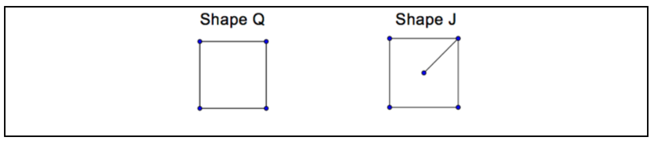

Figure 1. Two cards presented in the scenario as examples of polygons

We collected responses from 25 secondary mathematics TCs in methods courses at two large, public research institutions. Seventeen participants were engaged in a yearlong post-baccalaureate licensure program at one institution. Eight participants from a second institution were enrolled in a shared methods course across multiple licensure programs. The methods courses in both programs incorporated practice-focused teacher education pedagogies, such as coached rehearsal. The full performance assessment (including two scenarios) was administered using Qualtrics in October 2016. TCs completed the assessment individually during the methods class. Response times for the full assessment ranged from 11:24 (minutes and seconds) to 42:37, with a median duration of 25:34.

We used a priori and emergent codes to describe features of TCs’ response to student errors in the dialogues. Examples of codes included talk moves used by TCs, such as re-voicing (Chapin, O’Connor, & Anderson, 2013), asking funneling or leading questions, and a focus on comparing the two shapes. We used similar codes to describe the features of TCs’ rationales. Examples of codes for the rationales included the rationale mentioning wanting to resolve the error, or the rationale mentioning the need to recognize and/or value student contributions. Using these codes for the dialogues and the rationales, we developed a series of yes or no questions to ask of each dialogue and rationale. These questions fell into three main categories: attending to the error, attending to the mathematics, and attending to students. Two authors independently answered the questions for each dialogue and rationale. Inter-rater reliability was assessed and disagreements were resolved through discussion.

Next, we engaged in a process of analytic memo writing and theme building (Miles, Huberman, & Saldaña, 2013) to identify the most salient features in the dialogues and in the rationales. As we looked at counts of dialogues or rationales with particular features, we kept in mind that the absence of evidence was not the same as evidence of absence. For example, though 15 TCs explicitly mentioned that Jessie’s contribution contained an error, other evidence demonstrated that all participants understood Jessie’s error. To address the relationships between TCs’ rationale and dialogue, we utilized a matrix highlighting relationships among dialogue features and rationale features (Miles et al., 2013). We used the three categories of questions in our analyses of the dialogues and the rationales to explore connections between the two. This allowed for a coordination of TCs' approaches to responding to errors, as demonstrated through the dialogue, and TCs' goals for responding to errors, as demonstrated through the rationale.

Findings

We report findings for each research question around the three analytic themes: (1) attending to the error, (2) attending to the mathematics of the task, and (3) attending to the students.

Theme: Attending to the Error

RQ1: Features of TCs' dialogues. One striking feature of the dialogues was the way in which the error was resolved or corrected in a few lines. This occurred in nine of 25 dialogues. In five cases, the original student corrected their own error, as in the example below:

> Teacher: It does look like a square but what is different about Shape J and Shape Q?
> Student: There is a line from one corner of the square to the center.
> T: Correct, what do you think we can conclude by noticing the line from the corner?
> S: We can conclude that this is not a polygon, because they are not all connected.

In the remaining four cases, another student corrects or resolves the error. Six additional dialogues included a last turn of talk in which the teacher posed a question that was potentially leading toward resolving or correcting the error through the next student response. These 15 cases illustrate the common approach of resolving errors quickly, and often in a one-on-one exchange between teacher and student, or as the result of a pointed question from the teacher.

In contrast, some TCs wrote dialogues in which the error was not resolved. One TC used a "tabling" move—explicitly pausing the conversation without resolving the error. Five dialogues ended with the teacher asking for a student to contribute a new card to the discussion, which signaled the discussion moving on without immediate resolution of the original error. One TC did not explicitly address Jessie's contribution and centered the dialogue around a third shape:

> T: Does anyone have another example of a polygon?
> S: Shape M [a parallelogram].
> T: Why do you think shape M is a polygon?
> S: All the sides are straight.
> T: Before I get another example, I want us to take a look at what we have up here. How are these shapes up here different from one another? Do we all believe they are all polygons?

This set of cases suggest a recognition of approaches, such as eliciting new ideas, that can continue a discussion while a student error is not necessarily resolved in the moment.

RQ2: Features of TCs' rationales. An explicit part of a majority of the rationales (15 of 25) was an acknowledgement that Jessie has made an error (or, in some TCs' word, a "mistake"). This indicates that: (1) TCs recognized the mathematical issue at hand, and (2) TCs' dialogues were constructed in a way where responding to an error was a key factor. Five of these 15 rationales mentioned wanting Jessie to correct her own error, and six of the 15 mentioned wanting other students to recognize Jessie's error. The different ways in which TCs characterize Jessie's contribution ("misconception", "holes in [her] logic", a key consideration is missing) could impact the way in which TCs conceive of how to respond and, furthermore, what might be convincing to Jessie. These differences could result in different approaches to the dialogue.

RQ3: Relationships between TCs' dialogues and rationales. Of the 15 TCs who mentioned the error in their rationales, six resolved the error in their dialogues. An additional four dialogues approached resolution in their final talk turn. The remainder responded to the error in other ways, such as moving on to discuss a new card. This indicates that for the TCs who focused on the error in their rationales, the typical response was to move toward resolving it, with a smaller number of TCs addressing the error through continued discussion.

It is also interesting to note what is not included in the rationales, given the features of the dialogues. For example, no TCs mentioned that Jessie's error needed to be or could be resolved quickly. While many of the TCs who acknowledged that Jessie's contribution was an error also suggested it needed to be resolved at some point, no one suggested that this would necessarily happen in a few turns of talk. Yet, in many dialogues, the error was resolved or was soon-to-be resolved. We see this incongruity as potentially highlighting an implicit expectation that some conclusion be reached in the assigned five to eight lines of dialogue. It may also be that TCs do not wish to correct an error with their immediate response, but feel that what one TC referred to as, "a few well-placed questions," could be a sufficient way to respond to and resolve an error.

Another example is that no TCs mentioned any external factors, such as time, curriculum, or testing, as influencing their dialogues. While, as an approximation of practice these performance tasks are intended to reduce complexity, it is interesting to see how TCs' dialogues could still have less-than-productive features that are commonly explained by appealing to these constraints. This represents another incongruity, in which TCs do not explicitly appeal to common classroom constraints, yet still put forward a dialogue in which student reasoning and mathematical meaning are not kept central. Overall, these tensions between TCs' approaches and goals highlight the support TCs need around productively responding to errors.

Theme: Attending to the Mathematics of the Task

RQ1: Features of TCs' dialogues. TCs attended to mathematics in their dialogues in several different ways. Almost all dialogues (23 of 25) included a teacher move drawing attention to the difference between Shapes J and Q. Of these 23, 17 dialogues had this as the first teacher move. This approach to the mathematics is necessarily dependent on the particular task being discussed, and some dialogues contained approaches that might be used in multiple contexts. For example, six dialogues used the word "definition". This shows attending to the specific features of a polygon under consideration. Seven dialogues introduced an additional shape to the discussion (as shown in the dialogue above), with the shapes chosen reflecting attention to the features of the definition requiring exploration. The approaches of focusing on the definition and introducing a new example are teaching moves that can be used across contexts. The two TCs who did not explicitly address the differences between shapes J and Q introduced new shapes to the discussion, indicating that all 25 dialogues attended to key mathematical ideas.

RQ2: Features of TCs' rationales. Half (13 of 25) the TCs mentioned moving toward the mathematical goal—establishing and clarifying the definition of a polygon—in their rationales. In some cases, this was fairly general, with references to the "definition" or "objective." In other cases, TCs highlighted specific mathematical features of the goal. For example, one TC explained that their dialogue was constructed in order to support Jessie to, "realize the other defining feature of a polygon, that sides can only meet one other side at the endpoints."

In addition to the 13 TCs who mentioned the goal, eight TCs wrote about a desire to have students consider the differences between Shapes J and Q, though they did not explicitly connect that idea to pursuing the goal of the activity. Five of those eight further specified the key difference that Shape J has an "extra segment" that intersects with two other segments at one endpoint and does not intersect with another segment at the other endpoint. Finally, one other TC generally mentioned students needing to consider "one more property of a polygon."

Altogether, 22 of 25 TCs referenced something related to the mathematics of the activity. There was a strong emphasis on an aspect of the provided definition of polygons that does not come out in either student's contribution—that each side is a line segment that intersects exactly one other side at each endpoint. We use these analyses as evidence that TCs attended to the mathematics of the scenario, which has implications for the dialogue they constructed.

RQ3: Relationships between TCs' dialogues and rationales. The prevalence of attention in TCs' rationales to the mathematics of the scenario is closely connected to our finding that almost all the TCs focused the discussion in some way on the differences between Shapes J and Q. It is possible that focusing students' attention on the differences between the shapes (with a pointed prompt, for example) is seen as the way to make progress toward the goal of the activity.

We identified two interesting exceptions to this trend. The two TCs who did not draw any attention to the differences between Shapes J and Q in their dialogue either elicited a new card from students or offered a new shape that was not represented on another card. These cases illustrate how a discussion, in response to this scenario, can focus on key mathematical ideas without an explicit prompt about the differences. Given the role that introducing a new shape played in dialogues that did not result in a quick resolution of the error, we consider this approach productive, assuming the decisions made about the new shapes are purposeful.

Another exception is represented in the second dialogue above, where the teacher starts by asking for a new card and ends with a question about the differences among the three cards. This TCs' rationale was one of the few that made no explicit reference to the mathematics of the task. Instead, the rationale emphasized a goal that students maintain "skepticism" and be able to "speak up when something does not seem right to them." This provides an interesting case of how a focus on providing space for students to reason, even without mentioning particular mathematical ideas, may give rise to productive approaches to responding to errors.

Theme: Attending to the Students

RQ1: Features of TCs' dialogues. TCs brought students into their dialogues in multiple ways. Nine introduced a new student, sometimes using a new name. Three others reintroduced Rosalia. Some TCs used moves such as orienting students to one another (5), re-voicing (9), recording student thinking (2), and using positive language to describe student thinking (8). "Telling" in the discussion was also sometimes used as a way in which TCs attended to students, and nine dialogues included some form of telling. Many dialogues attended to students using more than one of these approaches, and 21 of 25 dialogues attended to students in at least one of these ways. Of the four remaining dialogues, all included some form of leading or funneling questions, and several were not written as a true dialogue (i.e., not in transcript form), which showed little explicit attention to including student voice. Among the 21 dialogues attending to students, all had a teacher talk turn between every student talk turn. These results highlight the variety of approaches TCs use in imagining responses in these hypothetical scenarios.

RQ2: Features of TCs' rationales. A key feature of the rationales was a desire to respond in a way that valued students' opportunities to reason mathematically. Nine TCs made specific mention of approaches and goals such as: "exploring", "discovery", "comparing", "critical thinking", or "connecting" in reference to student thinking. Four other TCs discussed wanting to value or draw on Jessie's or Rosalia's reasoning. This signals a set of principles in which student reasoning should be supported and made central.

Other TCs' rationales focused on the specific moves they used in their dialogue. Two TCs highlighted "orienting" moves in their dialogue (e.g., having a student re-voice or reason about a peer's contribution). In four other cases, TCs mentioned what we called "telling" moves (e.g., restating and summarizing ideas, giving new examples), and recording ideas. While moves such as these do not necessarily explicitly draw upon student reasoning in the way that orienting moves do, they are powerful moves that support students' sense making and reasoning. Other mention of moves in rationales raised questions for us. For example, some TCs mentioned the use of "guiding questions," positioning this approach as productive. However, as we interpreted these cases, we inferred "guiding" to mean "leading" or "funneling" and not as something that was necessarily responsive to or supportive of student thinking. In total, 18 TCs mentioned valuing student reasoning or using specific teaching moves related to student thinking.

RQ3: Relationships between TCs' dialogues and rationales. We focus here on the four dialogues that were not coded as attending to students. What is striking in these cases is that all four of the related rationales mentioned attending to or valuing students in different ways. For example, one TC wrote that they wanted to "use Jessie's mistake" to "help the class understand." However, this TC did not produce a true dialogue. Rather, they listed questions and answers without any evidence of student voice. Another TC mentioned wanting students to do the mathematical work, saying "The kids need to come up with the other rules and they will end up sorting that out." The associated dialogue in this case has six talk turns focused on the differences between Shapes J and Q, and then a note from the TC that they would "move on from here and see how everything else was sorted to see if we can add to our rule." These findings point to a need to be cautious what taking what a TC says about their approaches and goals for teaching, even in the context of a specific scenario, and making claims about skilled teaching practice.

Discussion and Conclusion

Our use of a written performance task provided a lens for investigating TCs' developing practice. We gained insight into their coordination of approaches and goals related to responding to student errors in whole-class discussion. In both the approaches (represented by the dialogues) and the goals (represented by the rationales), three themes emerged that characterized TCs' perspectives on responding to errors: attending to the error, attending to the mathematics, and attending to students. At times, dialogues and rationales presented approaches and goals in alignment with one another. However, in several notable cases, we observed incongruities between TCs approaches and goals around responding to errors.

Our results suggest several potential areas for growth around teacher learning. In cases where approaches and goals are mostly congruent, we observed TCs wrestling with the dilemmas highlighted in earlier literature around responding to student errors. In the cases where approaches and goals were not congruent, we saw misalignment in two directions. Some TCs wrote about productive goals for responding to errors in their rationales but their dialogues did not have features associated with productive responses. Other TCs wrote dialogues that included productive responses to student errors, but rationales that did not clearly articulate productive goals for their responses. This suggests that part of the work of teacher education is to provide TCs with productive approaches to responding to errors in concert with developing their understanding about why those approaches are productive. Approximations of practice support this work, providing opportunities for TCs to demonstrate and further develop adaptive skill in interactive and contingent moments of teaching.

Next steps for this work include examining the ways in which TCs' responses to the performance tasks change over the course of their participation in the methods course. This will allow us to explore how coordinating approaches and goals changes over time. Additionally, we plan to explore how the responses to the written performance task relate to features of TCs' rehearsals and enactments focused on leading whole-class mathematics discussions.

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