CASES OF LEARNING TO RESPOND TO ERRORS THROUGH APPROXIMATIONS OF LEADING WHOLE-CLASS DISCUSSIONS

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The emerging use of approximations of practice in teacher education calls for ways to document teacher candidates' (TCs') skill from their enactments and to determine how TCs' skill develops through such pedagogies. We highlight two cases of secondary mathematics TC development, connecting analyses of two types of approximations—coached rehearsals and scripting tasks—with a focus on the practice of responding to errors in whole-class discussion. Each case illustrates a distinct example of TC development. This work contributes to the research on pedagogies of practice in teacher education by offering approaches for understanding TC practice and development through multiple data sources.

Keywords: Teacher Education-Preservice; Instructional Activities and Practices

The use of approximations of practice (Grossman et al., 2009) in teacher education offers a promising way for teacher candidates (TCs) to develop skill with key aspects of the work of teaching. There exists the need to document TCs' skill from their enactments and to identify the way in which TCs' skill develops through such designs (Janssen, Grossman, & Westbroek, 2015; Shaughnessy, Boerst, & Farmer, 2019). In this paper, we connect analyses of two types of approximations—coached rehearsals and scripting tasks—to investigate the relationships between learning opportunities and evidence of learning captured across time. We use two cases to illustrate what can be learned about TC development through these multiple data sources.

Literature Overview

Leading whole-class discussions is complex work. It includes eliciting, responding to, and building upon student contributions in ways that move the discussion toward mathematical goals (Boerst, Sleep, Ball, & Bass, 2011; Leatham, Peterson, Stockero, & Van Zoest, 2015; Sleep, 2012). While errors—contributions that are incomplete, imprecise, or not yet correct—are key to students' learning process (Brodie, 2014), they are often positioned negatively when teachers quickly correct them or avoid them entirely (Bray, 2011; Santagata, 2005; Tulis, 2013). This can potentially remove opportunities for students to make sense of errors. During whole-class discussion, teachers must also balance the needs of the student who contributed the error with the needs of the rest of the class, who may or may not share that student's conception. For these reasons, we focus on this practice in our work investigating TC learning.

Coached rehearsals, an approximation of practice, can afford opportunities for TCs to develop a vision of ambitious and equitable practice; understandings of students and content; dispositions regarding students, content, and teaching; and a repertoire of practices and tools (Ghousseini & Herbst, 2016). In this approximation, one TC takes on the role of teacher while other TCs take on the role of the students, and the teacher educator provides in-the-moment coaching (Kazemi, Franke, & Lampert, 2009). TCs engage in the interactive work of teaching, such as making sense of and responding to student reasoning during discussion. TCs' enactments during approximations of practice also provide a lens for teacher educators and researchers to assess TCs' developing skill and their coordination of approaches and goals.

We also use "scripting tasks" as an approximation that puts TCs in a 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 classroom scenario and then 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.

Perspective on Teacher Learning

Hammerness and colleagues (2005) assert that teachers must be supported in learning communities and enabled to develop tools and practices, vision and dispositions, and understandings. This framework guides our research on TC learning through approximations. Tools and practices encompass a sense of when, where, why, and how to do the work of teaching. Vision represents teachers' sense of where they are going and what is possible in teaching, which are connected to dispositions, which relate to commitments toward professional growth and inquiry into practice. Understandings represent a teacher's deep knowledge of their subject and how to make it accessible to others, including knowledge of how students learn and develop particular ideas. Taking this perspective, we ask the following research question: What forms of TC learning are evident through their work with multiple approximations of practice? In particular, we focus on evidence of TCs' practices and vision as they develop over time.

Methods

Our work is the product of an ongoing, multi-year collaboration situated in secondary mathematics methods courses at two large, public research institutions. At "Institution A", TCs are enrolled in the methods course as part of a yearlong post-baccalaureate licensure program. TCs from "Institution B" are enrolled in a shared methods course across multiple programs. At both sites, TCs completed the scripting task (Baldinger, Campbell, & Graif, 2018a) twice: early in the methods course ("Initial") and then again near the end of the course ("Follow-up"). The scripting scenario we highlight in this paper depicts whole-class discussion around a sorting task (Baldinger, Campbell, & Graif, accepted), where students are asked to sort shapes into examples and non-examples of polygons. The scenario concludes with a student, "Jessie," contributing an error. TCs are prompted to assume the role of the teacher and write a dialogue of how the conversation would continue. TCs also write a rationale for how they constructed their dialogues.

In between the two implementations of the scripting task, TCs participated in coached rehearsals of a sorting IA (Baldinger, Selling, & Virmani, 2016) focused on defining linear functions. For all rehearsing TCs, the mathematical focus and the sets of cards to be used were provided by the teacher educator, with common materials used across sites. In order to ensure that these rehearsals include opportunities for responding to errors, we used "planted errors" (Baldinger, Campbell, & Graif, 2018b). Non-rehearsing TCs contributed these instances of student thinking during the rehearsal, enabling the teacher educator to stay in the role of coach while providing more authentic student voice to the rehearsal. After a set of rehearsals, TCs completed reflections, in part through video annotation, which serve as additional data.

For this paper, we zoom in on the experiences of two TCs, one from each site, purposively sampled to represent the range of TC learning that might be visible through these different approximations of practice. We selected TCs who rehearsed one of the sorting IAs. From Institution A, we highlight the experience of Greg (all names are pseudonyms). Greg was often quiet during class discussions, and showed off his engaging personality during interactions with students. In his sorting IA, students were asked to sort graphical representations into examples and non-examples of linear functions. The planted error involved a student asserting that the graph of a vertical line ($x = 2$) was a linear function because it looked like a straight line.

From Institution B, we highlight the experience of Travis. He regularly exhibited thoughtfulness about the work of teaching in his contributions in the class. In Travis's sorting IA rehearsal, students were asked to sort tabular representations into examples and non-examples of linear functions. The planted error involved a student looking only at the change in the y-values in a table and concluding that the table did not represent a linear function because the change in y was not constant. However, the change in x-values was also not constant, and looking at the changes in x- and y-values together would reveal that the table did have constant slope.

Using the themes developed through our analysis of data from the larger study, we looked holistically across the data in each case for evidence of learning related to each aspect of framework for learning to teach (Hammerness et al., 2005). We considered features of each approximation such as the types of teaching moves used, the representations of student voice, and the way in which each TC attended to the mathematics. We investigated vision and dispositions through exploring TC reflections on their own practice. In presenting these findings, we aim to develop a picture of each case not for the sake of comparing the two cases, but rather to illustrate the range of learning captured across these different approximations of practice.

Findings

In this section we share the cases of Greg and Travis to provide two distinct images of TC learning, and two instances of how that learning can be documented through coordinated analysis across two distinct approximations of practice.

Trying New Practices, Changing Vision: Greg

Scripting task. Greg demonstrated some notable differences in his two responses to the scripting task polygon scenario (see Table 1). In the Initial dialogue, Greg first calls students' attention to the "extra line" in Shape J. This starts a series of funneling questions to get Jessie to quickly correct how shape J is sorted. In contrast, the opening move in the Follow-up dialogue asks for additional arguments in support of classifying shape J as a polygon.

Table 1: Greg's Initial and Follow-up Dialogues

Initial Dialogue		Follow-up Dialogue	
Teacher:	well what about this extra line here? Does it make a difference?	Teacher:	Who can tell me another reason why shape J is a polygon?
Jessie:	Idk, maybe	Student:	Like Rosalia said, all of the sides are straight.
Teacher:	What does it mean to be a square?		
Jessie:	All sides are equal length and opposite sides are parallel	Teacher:	Who can tell me why shape J might not be a polygon?
Teacher:	So does this fit the definition of a square?	Student:	There is that line in the middle so it is not really a square.
Jessie:	No, that line isn't parallel to anything	Teacher:	Can someone expand on what _____ just said?
Teacher:	So what can we say about it being	Student:	Well that segment has one end not

Otten, S., Candela, A. G., de Araujo, Z., Haines, C., & Munter, C. (2019). *Proceedings of the forty-first annual meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education*. St Louis, MO: University of Missouri.

	a polygon?	meeting any other sides.
Jessie:	that it is not because that line only connects to that one edge and the other lines have to [*sic*] edges	

The Initial dialogue includes only conversation between the teacher and Jessie, making no effort to incorporate other students. In the Follow-up dialogue, though the students are not named, it is possible that up to three different students participate in these few turns of talk. Another interesting feature of the Follow-up dialogue is how it concludes without any move to lead students toward a conclusion. It feels much more like a snippet of a longer conversation, as opposed to the Initial dialogue, which feels in some ways like a completed conversation.

Greg's thinking about why he constructed the dialogues in this way also changed (see Table 2). At first, he intended to draw on the definition of a square in order to correct the sort and move the discussion forward. In contrast, on seeing this scenario for the second time, Greg focused much more on engaging other students. Though he acknowledged Jessie had incorrectly sorted shape J, correcting that error was no longer the focus of his dialogue.

Table 2: Greg's Initial and Follow-up Rationales

Initial Rationale	Follow-up Rationale
The student is having a misunderstanding to what a square is, so I believe it is important for them to re-think what a square is and modify what they are saying about Shape J. From there it might be easier for the students to recognize whether it is a polygon or not.	Well I would want other students to think about why it is possible for J to be a polygon, but then I would also want other students to explain why they think it is not a polygon. Although it is not a polygon I want students to be thinking about both reasonings.

Greg pointed out many of these differences himself. In reflecting on how his response to the scenario changed, he wrote, "My questioning is much different, I tried to expand more one the original ideas rather than going straight to finding the 'right' solution." Greg did not see his Initial responses when he wrote this, but his recollection is strikingly accurate. The shifts in his dialogues and rationale, along with this final reflection, suggest changes in Greg's practices related to responding to errors, as well as his vision for dealing with errors.

Rehearsal. Evidence of Greg's changing practices and vision of responding to errors is clear in his rehearsal. Greg was the second of three TCs to rehearse the sorting IA. The rehearsal included discussion of five cards: two easy-to-sort examples of a linear function, two easy-to-sort non-examples, and one boundary case. The planted error was the first card contributed. Greg responded to the error by experimenting with orienting moves: "It's a straight line. Alright, you are correct, it is a straight line. Does anyone agree with this? Who agrees with this?" After one student agreed, Greg said, "Alright, does anyone disagree with this?" Several students contributed some disagreements, and Greg restated and recorded their reasoning. He then checked back in with the group that originally contributed the error:

Teacher: Okay, interesting. So, going back to your group, what do you think about this? Does your opinion change?

Student: It doesn't because my idea of what a linear function was, was a straight line. And even thought that line is up and down, it is definitely straight, there's no curves.

Teacher: Sounds good. Alright, we'll leave that here for now. We can come back to it.

Greg experimented with a tabling move, allowing the disagreement among the class to go unresolved for the moment as he moved the discussion on to additional cards.

Greg's approach to responding to student thinking was relatively similar for the contributions without errors. He continued to experiment with orienting moves, seeking agreement and disagreement from students. He recorded student thinking and received feedback from the teacher educator about his practice. Later, students discussed the graph of a step function. Some argued that the step function was not a line, and the teacher educator inserted disagreement, saying that the step function had constant slope, and thus represented a linear function. Through this conversation, Greg helped the class discuss the vertical line test as a way to determine whether or not a graph represented a function, and that led to the following conversation:

Teacher: Can someone give me a reason that they disagree that it needs to pass the vertical line test in order to be a linear function?
Student 1: Yeah, because of Graph D [the vertical line graph] that we were talking about earlier. For that one to be a function.
Student 2: But it's not a linear function.
Teacher: But it's a nonlinear function?
Student 2: But it says it's a linear function.
Student 1: Oh yeah, we left it in a gray area. Bah. Alright.
Teacher: Going back to [Graph D], do we all agree that it needs to pass the vertical line test in order to be a linear function? [Some students nodding] Unless someone's going to disagree? Give voice to that? [Pause] So if we come back to this [Graph D], does it pass the vertical line test?

This exchange shows how Greg was able to revisit the planted error while keeping the focus on student thinking. Many of Greg's moves in the rehearsal are consistent with his Follow-up dialogue. Following the rehearsal, Greg reflected that he "learned better ways to facilitate discussions by using better questions." He felt that "The timeouts were quite helpful, as I was able to stop the lesson and go back and fix what I did wrong." This illustrates Greg's intentional work on questioning and his changing vision about how to best respond to errors in the moment.

Complexity in What Gets "Taken Up" from Rehearsals and Coaching: Travis

Scripting task. Travis uses similar moves in both dialogues, but they are used in seemingly more productive ways over time (see Table 3). For example, the Follow-up dialogue starts with an orienting move instead of a question probing Jessie's reasoning. Also, the third line of each dialogue elicits agreement (or disagreement), yet the move in the Follow-up dialogue is not focused only on Jessie's contribution. These changes show shifts in approaching the error—from something to be targeted to something that is part of a broader conversation.

Table 3: Travis's Initial and Follow-up Dialogues

Initial Dialogue		Follow-up Dialogue	
Teacher:	What is your reasoning for determining that Shape J is a square?	Teacher:	Rosalia, can you re-state what Jessie was trying to say about Shape J?
Jessie:	Well it has 4 straight sides of equal	Rosalia:	I think Jessie said that Shape J is a

	length that are connected.		polygon because it is a square.
Teacher:	Does anyone else agree with Jessie, that Shape J is a square, and therefore a polygon?	Teacher:	Alright, does anyone agree or disagree that Shapes Q and J are polygons because they are squares?
Melinda:	I disagree that it is a square and a polygon.	Student:	I don’t think Shape J is a square. A square only has 4 sides that are straight lines. That shape has 5 straight lines.
Teacher:	And why do you believe that?	Teacher:	What do you think about what student said about this shape not being a polygon because it isn’t a square?
Melinda:	Well it looks like a square with an extra line inside of it, and that line isn’t connected to another line on both sides. So it isn’t a square or a polygon.	Jessie:	If we are looking at the shape as a whole, then it would make sense that it isn’t a square. If you ignore that diagonal line, we have a square, but I don’t think we can do that after hearing that explanation.
Teacher:	Could you say in different words why you think it is not a polygon?		
Melinda:	The figure has a side that is not connected to two other sides. (Teacher records this reasoning on the board)		

Another difference is the way the error gets resolved. In the Initial dialogue, since only Melinda’s idea is recorded, it suggests that the error has been corrected without any input from Jessie. Alternatively, in the Follow-up dialogue, the teacher checks back in with Jessie after another student contributed a disagreement. While Jessie appears to become convinced with this new information, we see how Travis is considering ways to involve Jessie in that work.

We can connect these observations to Travis’s rationales (see Table 4). His Initial rationale was focused on probing Jessie’s thinking and eliciting other students’ ideas. The rationale also confirms the inference that the last moves were an effort to highlight correct ideas about polygons. The Follow-up rationale details the deliberate decisions being made to use moves that clarify the ideas being discussed, to elicit agreement or disagreement (though without singling out a particular idea), and to go back to Jessie as part of resolving the error in-the-moment.

Table 4: Travis’s Initial and Follow-up Rationales

Initial Rationale	Follow-up Rationale
It is always useful to allow students to explain their reasoning out loud. It helps this practice explaining their thoughts in mathematical terms as well as giving other students opportunities to engage with each others’ [*sic*] thoughts. Then the teacher asked for another student’s opinion to give another student a chance to either restate what has already been discussed or to give a different opinion/thought process on the situation. The teacher asked questions to help the student try to dive deeper into why she did not think it was a polygon and therefore getting more information out	I think it is important to have crucial parts of the discussion be re-stated so that everyone is clear about what we are discussing specifically. I also thought it was better to ask the class to agree or disagree with both shapes Q and J so that it did not seem as if the teacher was singling out one of the cards, giving a cue to the students that the point made about the card was probably wrong. After a correct description was given about the card, it is important to go back to the student who had an incomplete conception about the card to ensure that they understand

there to help students understand the requirements/definition of a polygon.	where their mistake was and why the card can be sorted as a non-example.

Based on his recollection of his Initial response, Travis noted that his focus on "coming back to the original student who made the statement with an incomplete conception" was a change. He "tried to focus the discussion on the goal more than I did the first time," which might explain the Post-dialogue correcting the error. These shifts suggest changes in Travis's practices and vision, and also provide insight into what does not seem to change in the dialogue alone.

Rehearsal. Making sense of Travis's development is supported by considering his rehearsal. Travis was the third of three TCs to rehearse the sorting IA. His rehearsal included discussion of four cards: two easy-to-sort examples of a linear function and two easy-to-sort non-examples. The planted error (Table D) was the first non-example shared and was revisited later by another student. Travis elicited more reasoning about Table D from the student, recorded ideas, and confirmed that he was representing the idea accurately—all moves consistent with his Pre-dialogue. Travis then elicited other non-examples, implicitly tabling the conversation about the planted error. This move was consistent with how he initially responded to all cards.

Travis's intention to move on was challenged by other students wanting to disagree. After asking for additional non-examples, he allowed a student to comment on Table D. After the student shared a lengthy contribution, Travis turned to the teacher educator and said:

Teacher: Okay, so I guess now this would be - what I'd like to talk about now is sort of the difficulty to get closer down to the definition of it. But I don't know if I want to talk about that yet.

Coach: Then yeah, I think that's a sound decision. So, one thing you could have done with [Student] wanting to comment, is you could have tabled that and known to go to [Student] whenever there is an opportunity to raise any questions or disagreements or whatever. But prior to that it seemed that you were willing to move on to the next card. So that's great.

In his reflection on this moment, Travis expressed wanting to respond to the error in a way that did not make it, "seem as if I single [*sic*] out the one person who makes an incorrect statement with an incomplete conception." This may explain the tabling move, and also highlights the way Travis negotiated valuing students' ideas while pursuing the goal. In reflecting on the second contribution about Table D, Travis noted that the student, "made an important distinction here where he began to discuss the how the x-values are changing relative to the y-values," but that he got "lost" in the student's ideas.

This example speaks to the power of considering multiple data sources. Looking only at the rehearsal, we might claim Travis was experimenting with tabling moves as a response to errors. From the scripting tasks, we might claim that Travis did not "learn about" tabling moves and wants to correct errors relatively quickly. Together, we see that Travis's takeaway seems to be a negotiation of valuing student contributions while also making progress toward goals.

The rehearsal also helps explain Travis's attention to checking back in with the student who contributed the error. Once students shared reasoning about Table D as an example of a linear function, the teacher educator reminded Travis to check back in with the student who originally initially contributed Table D. Travis later turned to that student:

Teacher: [Student 1], how would you use these change in *y*'s versus these change in *x*'s to show that this is an example?

Student 1: So, I get that the *y*'s and *x*'s are both changing at different rates, but I don't understand like how they're connected. So, like, I get that the *x*'s aren't constantly changing by 1 and the *y*'s aren't, but how does that make it—I still don't understand how that would make it an example.

Travis elicited an explanation from another student about the specific relationship of the changes in *x* and *y* and recorded those ideas. He then checked back in with the original student:

Teacher: [Student 1], does what [Student 2] was discussing there, does that make more sense about how we're relating the change in *y*'s to the changes in *x*?

Student 1: Yeah, I think I get it now, because you have to divide the change in *y* by the change in *x* to find what the slope is. And when you actually do it, it gives you 6 every time. I think I get it now.

Checking in with original student in the Follow-up dialogue had roots in Travis's rehearsal. Reflecting on this moment of his rehearsal, Travis noted that he, "made it a priority to come back to [Student 1] to ensure that he had understood what his errors in thinking were." The check in move helped realize two key aspects of Travis's vision—valuing students' contributions and making progress toward a mathematical goal. Even though the student was not initially convinced, the student was eventually able to articulate the correct idea, which is consistent with Travis's Follow-up dialogue. Looking across these approximations enables us to make more meaningful claims about TC learning and what experiences contributed to that learning.

Discussion & Conclusion

Through this work, we respond to the need to document TCs' skill from their enactments through approximations of practice and how to identify the way in which TCs' skill develops through such designs (Janssen et al., 2015; Shaughnessy et al., 2019). Through our analysis of two TCs' engagement with multiple approximations of practice, we highlight characterizations of skill and a more nuanced understanding of TC development across approximations. The cases of Greg and Travis illustrate different manifestations of skill and development that contribute to sensemaking of TCs' work through approximations—both in-the-moment and over time.

Greg's developing practices, made evident through differences in his dialogues, had direct connections to the moves he experimented with during his rehearsal. While these practices were continually developing throughout the rehearsal, their use in response to errors seemed to shape his vision of how discussions around errors could unfold without the need for immediate resolution. Travis also demonstrated through his dialogues how his practice of using orienting moves continued to develop as he refined the purpose for using these practices. Travis's rehearsal provided opportunities to experiment with moves and experience discussions around errors that play out in novel ways. While this contributed to his developing vision that included a valuing of students' ideas, that was being negotiated with a developing focus on how discussions are moving toward a goal. This resulted in Travis's focus on involving students who contribute ideas in the continued discussion of that idea (particularly involving resolving errors).

A main takeaway from these two cases is how the variety of data sources—across multiple approximations and time—offer a more complete picture of TCs' developing practice and the way a vision of teaching informs that practice. These cases highlight how looking at only one approximation or only at TCs' enactment would result in an incomplete picture. We see this work contributing to the field of research on pedagogies of practice in teacher education by offering approaches for understanding TC practice and development through multiple data sources. While we have focused our work on supporting TCs around the practice of responding to errors in whole-class discussion, we see these findings as having implications for the broader body of work and a focus on other focal practices.

Acknowledgments

We gratefully acknowledge the work of Foster Graif, Sean Freeland, and Josh Karr in contributing to analyses related to this paper.

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