WHAT DO THE EMERGING THEMES IN HIGH SCHOOL TEACHERS' JOURNALS TELL US ABOUT THEIR THINKING?

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We examine in-service high school teachers' journals to explore the emerging themes in a mathematics content course for their professional development. We use a sociocultural perspective and characterize journals as signifying teachers' communication and written discourses about their thinking and experiences in the course. We use applied thematic analysis to analyze the emerging themes. Our results demonstrate the complexity of teacher thinking and suggest that teachers do not necessarily separate their thinking about themselves or mathematics from their thinking about their students; similarly, they can take different roles as teachers and learners in a given context. Our results indicate exercising caution about potentially operating with an oversimplified picture of teacher thinking via compartmentalized pieces, especially if such frameworks are used to measure teacher thinking, knowledge, and development.

Keywords: Communication, discourse, professional development, calculus

Introduction

Journal writing has been used in mathematics education for various purposes. Our literature review about journaling revealed that, in the context of mathematics education, journals were mostly used with students. Such work examined students' mathematical thinking and cognitive skills; problem solving; their beliefs and attitudes about mathematics, and rarely, their mathematical communication (e.g., Baxter, 2008; Farmer et al., 2003; Liljedahl, 2007; Rolka et al., 2006). Journals have also been used in teacher education, particularly in relation to reflective thinking and practice (e.g., Schön, 1987). Considered mainly as reflection tools,—although what is meant by reflection is rarely defined in these works— researchers used journals to examine teachers' professional knowledge and experience; professional identity; dispositions and beliefs in teaching and learning; pedagogical and professional development; their reflective and critical thinking on various issues; and experiences in their teacher education programs and courses (e.g., Joseph & Heading, 2010; Garmon, 2001; Mewborn, 1999; Snyder, 2012). Compared to the literature on journaling in the context of general teacher education, the literature on journaling specific to mathematics teacher education is sparse and primarily focuses on pre-service teacher education at elementary levels. Our work focuses on examining in-service high school mathematics teachers' journals in the context of a mathematical content course they took as part of their professional development since what teachers take from their experiences in professional development remains a challenging issue to address in mathematics education research (Farmer et al., 2003).

Regarding the theme of PME-NA, our work challenges (a) the dominant cognitive approach that is often used while examining reflection as well as student and teacher journaling, and (b) the traditional psychological approach that views participants' accounts of events and their experiences as unreliable, implying a mistrust towards "subjects" of a study. We will use a sociocultural approach to conceptualize reflection and journals and consider our participants' accounts of their experiences as authentic sources through which we can gain more information about their thinking and development in professional development settings. We address the

following questions: What themes emerge in high school teachers' journals in relation to their thinking in a calculus content course they took for professional development? What do the emerging themes in these teachers' journals indicate regarding their thinking, knowledge, and development? Our findings challenge the dominant trends in mathematics teacher education research that view teacher knowledge as consisting of distinct types or pieces of knowledge that can be identified and measured through multiple-choice tests, mainly conceptualized from the perspective of the researchers (rather than those of teachers), and mainly utilizing cognitive perspectives.

Theoretical Framework

The study uses a sociocultural perspective that conceptualizes thinking as communicating and discourse as a "special type of communication made distinct by its repertoire of admissible actions and the way these actions are paired with re-actions…discourses in language are distinguishable by their vocabularies, visual mediators, routines, and endorsed narratives" (Sfard, 2008, p. 297). From this lens, thinking and communicating are not viewed as separate but connected activities; examining learners' discourses (communication), is tantamount to examining their thinking. Consistently, we characterize journal entries as written endorsed narratives involving the reflections (defined as meta-level discourses, i.e., discourses about discourses) of the teachers with respect to mathematics, their pedagogical approaches and practices, and their overall experiences and thoughts in the course. We view journals as written discourse with a communicational function (with one's self or others). By examining journals, we explore the (emergent) thinking of teachers in relation to the professional development course. Rather than viewing journals as signifying potentially "unreliable" accounts of participants' thinking, we view them as consisting of narratives that provide us with authentic information, from the participants' perspectives, of what they consider to be an honest account of their thinking and experiences.

Sociocultural approaches also highlight the interpretive aspect of research and the importance of context in meaning-making (Denzin & Lincoln, 2000). Consistently, we do not consider the narratives of the teachers in their journal entries as proxies for (often decontextualized and generalized) entities such as their cognitive schema, knowledge (or lack thereof), metacognition, beliefs, or attitudes. We consider these narratives as contextual indicators of teachers' discourses and thinking, keeping in mind that, while these narratives signify the authentic voices of the teachers, research is also an interpretive process that includes the researchers' presuppositions, theoretical perspectives, and personal stories (Denzin & Lincoln, 2000).

Background

This work is part of a larger study that took place in a postsecondary mathematics content course on calculus taken by in-service high school teachers as part of their professional development requirements (in our case, there was also one pre-service teacher taking this course, which was a programmatic exception). The researcher was the instructor of the course. The larger study hypothesized that an instructional approach that specifically attends to the tacit aspects of the mathematical discourse on various calculus concepts could support teachers' learning of those concepts (Güçler, 2016). A critical component of instruction was to elicit rich classroom discourse as well as reflection on and explication of teachers' mathematical discourses to promote learning.

Since we wanted reflection (meta-discourse) to be a continuous and consistent aspect of the course, the teachers also kept weekly journal entries throughout the course where we asked them

to reflect on any aspect of the course that they wanted. We collected these journals thinking that they would give us more information about how the teachers' thinking about calculus concepts evolved over time and help us triangulate the data we obtained. Further, we wanted to elicit teachers' authentic voices about their own experiences independent of the potential constraints of the questions we posed to them in the pre- and post- explorations. Although the primary focus of the original study was on teachers' mathematical discourse, the journals gave us richer information that went beyond teachers' mathematical thinking and learning. This paper only focuses on the discursive themes that emerged from the teachers' journals as they reflected on their experiences in the course and the implications of the results in terms of teacher thinking, knowledge, and development.

Methodology

The participants of the study were 1 pre-service, 7 in-service high school teachers taking a mathematics content course on calculus over the course of 13 weeks. Except for the pre-service teacher, the participants' experiences ranged 4–12 years. The journal entries were collected in the course of a semester and consisted of 11 entries for each teacher. In these journals, the teachers were asked to reflect on any aspect of the course or classes without any specific prompt from the researchers. This task was deliberately left open-ended so that the teachers could write about whichever issue interested them or puzzled them from week to week, at their discretion, to elicit their authentic voices. Most teachers kept their journals electronically, as a text document. Three kept physical journals in the form of written notes, which were scanned and transcribed (verbatim) to electronic text documents at the end of the course. These electronic journals were later transferred to the NVivo 9 software package and all the emergent coding took place in this software environment.

We used applied thematic analysis (Guest et al., 2012) to examine the emerging discursive themes in the teachers' journals. Unlike the initial focus of the study which put teachers' mathematical discourses at the forefront through an a priori coding structure (we do not report on those in this paper), the emerging themes helped us identify the discursive patterns which put teachers' mathematical discourses at the background. In other words, in the context of these emerging themes, the teachers could still be communicating about mathematics, but our focus was not on their mathematical discourse per se but on the larger theme that included the mathematical communication.

In addition to the researcher, four doctoral students were involved in the coding and analysis of the data. The project team met each week; reported on and discussed the emerging themes; and compared the coding of the previous week and elaborated on the specific instances and cases in which our coding differed until we reached agreement. This iterative, generative, and interpretive process was repeated until saturation, eventually resulting in about 90% interrater agreement.

When coding, our first focus was on segmentation, which concerns how to bound the text (Guest et al., 2012). To assure our coding did not ignore the contexts in which the discourse emerged, we characterized a segment as consisting of an excerpt that signified a complete thought so that the meaning of the segment can "clearly be discerned when it is lifted from the larger context" (Guest et al., 2012, p. 52). Therefore, in our analysis, segments often consisted of multiple sentences, which also helped us avoid overrepresentation of themes and promoted exploring relationships among the themes.

The first themes in our initial examination of the journals emerged from contexts where the teachers referred to themselves as teachers (SAT: self as teacher) or learners (SAL: self as

learner). Future iterations of coding resulted in the emergence of subcategories under these two categories. We noted that, within the context of SAL, the teachers discussed their own content-related (mathematical) difficulties (CD) and communicated about their enhanced learning (EL) in the course. Under the theme of SAT, three sub-categories emerged: TC, which refers to the contexts in which teachers wrote about the factors they thought constrained their teaching; SD, which refers to the contexts in which the teachers wrote about their students' difficulties about mathematical content they either experienced before or can now anticipate; and TS, which refers to the contexts in which the teachers wrote about their teaching strategies. After further examination, two subcategories emerged under TS: ES, where the teachers wrote about their existing strategies, and FS, where they wrote about the strategies they would use in the future as a result of their experiences in the course. Other emerging themes included the contexts in which the teachers' talked about the influence of the instructor (II) and the influence of their peers (PI) in the classroom in shaping their thinking and experiences in the course.

Results

Space constraints do not allow us to elaborate on all the emerging themes and their relationships in detail, so we primarily focus on the themes SAL, SAT, and some of their subcategories and relationships since they were the most dominant themes in teachers' discourses in their journals. We want to highlight that we do not make claims about teacher identity in the context of our study because, although some aspects of the teachers' discourses in the themes SAL and SAT may give us some insights about their identities, we believe that the data we have about SAL and SAT is insufficient to provide a rich and meaningful depiction of the teachers' identities, which are multi-faceted and require a data collection process that goes beyond merely examining their journal entries.

In teachers' journal entries, we identified 166 occurrences of the theme SAL and 156 occurrences of the theme SAT. We identified 71 occurrences in which the participants referred to themselves as teachers and learners in the same context (SAL ∩ SAT). Therefore, in about 43% of all SAL contexts, the participants also referred to themselves as teachers and in about 46% of all SAT contexts, the participants also referred to themselves as learners. The following excerpts provide examples for the themes SAL, SAT, and SAL ∩ SAT. All the names used in the study are pseudonyms and Steve is the only pre-service teacher in the course.

[1] Lea: I now understand that 'one to one' means simply that each x value is paired with exactly one y value, with no two x's being paired with the same y (injective). Also, 'onto' is when all elements in both sets are used (surjective). I am glad that I learned about these terms and their definitions. (SAL)

[2] Carrie: As a teacher, my experience shows that modeling is very challenging for students. They struggle analyzing graphs to create a story and creating graphs for verbal models. Today's class activity would lead into a great discussion regarding modeling, slopes, displacement, velocity, acceleration, etc. This is an activity that I will use in many of my classes as well as share with many of my colleagues. (SAT)

[3] Martin: I am continuing to struggle with the concept of derivative. I am grasping the rules, but I am having trouble with the concepts and applications. I can now understand where students can have trouble when I teach this. The main issue I am having deals with the concept of continuity. There was a question on homework that dealt with whether the first derivative was defined but the second derivative was not. I still am having trouble

understanding that concept, so as a teacher I can now understand that my students may have trouble with similar issues as well. (SAL ∩ SAT)

As can be seen from these excerpts, the teachers' discourses indicate that they can take different roles as teachers and learners in a given context. In addition, their discourses also indicate that there may also be other themes or subthemes embedded in a given context in addition to SAL, SAT, and SAL ∩ SAT. For example, in excerpt [1], which is coded as SAL, Lea also mentions that she "now understand[s]" the terms and "learned about these terms and definitions", which indicate enhanced learning and/or understanding as a component of SAL. Therefore, we also coded excerpt [1] as EL, based on our definition of this theme. In excerpt [2], Carrie refers to herself as a teacher (SAT) but she also mentions the activity in her professional development course as an activity she will use in her own teaching as a future teaching strategy as a component of SAT. Therefore, we also coded excerpt [2] as FS. In excerpt [3], Martin refers to himself both as a teacher and a learner (SAL ∩ SAT). When writing about himself as a learner (SAL), Martin mentions his content-related struggles and difficulties, so this excerpt also provides a context for CD as a component of SAL. On the other hand, he associates the difficulties he has with derivative with the difficulties his students would have about the concept, so we also see the theme SD as a component of SAT in the same excerpt. The examinations of the segments we identified as signifying a complete thought reveal the complexity and dynamic characteristics of teacher thinking, knowledge, and development. Excerpts [1-3] show that, even in such a small set of exemplars, we can see the emergence of themes, subthemes, and how they can be intertwined in complex but crucial ways.

In this paper, we want to also focus on CD, SD, and contexts in which both themes occurred (CD ∩ SD). Note that excerpt [3] shows how a teacher can think about his own difficulties and his students' difficulties in the same context, and provides an example for the theme CD ∩ SD. In what follows, we provide examples for the themes CD and SD:

[4] Fred: Oh, I have to get out of the habit of thinking of a function as a single rule or rigid model describing a situation – think piecewise! I struggled with the functions defined piecewise in today's class. (CD)

[5] Sally: This week, we talked about why continuity and limits were connected and how they related to each other. Most students have difficulty understanding that if you have a continuous function then the limit exists but that doesn't necessarily mean that if the limit exists then the function is continuous. It is a one-sided relationship and tends to be misconstrued as relationship that works both ways. (SD)

We identified 91 occurrences of the theme CD, 86 occurrences of the theme SD, and 50 occurrences of the theme CD ∩ SD in the teachers' journals. Therefore, in about 55% of all CD contexts, the teachers also mentioned their students' difficulties and in about 58% of all SD contexts, they also mentioned their own content-related struggles in the course. This major overlap may be interpreted in various ways. This finding may be an indicator that teachers' own difficulties with calculus concepts can significantly inform their thinking about their students' difficulties and vice versa in a context. If that is the case, a potential association of CD with teachers' mathematical content knowledge and the association of SD with teachers' pedagogical content knowledge can be very problematic. The characterization of teachers' own mathematical thinking and knowledge as aspects of their mathematical content knowledge and their knowledge of student thinking as an aspect of their pedagogical content knowledge is quite common in mathematics education research focusing on teachers, where these "types" of knowledge are

characterized as distinct, albeit related, components of teacher knowledge. Our results, however, show that these constructs may be almost inseparable within a given context in a way that may make it very challenging to identify or measure which "type of knowledge" teachers may have at a given time, especially if such measurement is being made through one-shot multiple-choice tests or decontextualized assessment problems and/or instruments .

Another potential explanation for the major overlap may be due to the teachers' profound struggles in this calculus content course and, in the absence of familiarity with the conceptual aspects of calculus and rich thinking about student difficulties about calculus concepts, the teachers mainly referred to their own struggles as resources and means for anticipating most of the student difficulties about calculus. In fact, there is some evidence in our data that the teachers who struggled most with the content were also those whose discourses included a larger number of occurrences for the theme CD ∩ SD.

Within the context of SAL, the relationship between CD and EL may also be worthy of some elaboration. In teachers' journal entries, we identified 91 occurrences of the theme CD, 53 occurrences of the theme EL, and 27 occurrences of the theme CD ∩ EL. In about 30 % of all the CD contexts, the teachers also mentioned enhanced learning or understanding and in about 51% of all the EL contexts, they also mentioned their content-related difficulties. The following excerpts provide examples for the themes CD, EL, and CD ∩ EL.

[6] Milo: I had a bit of confusion today when we started discussing derivative. If I recall, finding the derivative of basic functions is not too difficult, but understanding the meaning behind it and why-that's created a headache for me today since I don't know those meanings. (CD)

[7] Steve: I believe I am leaving this class with a better understanding of every calculus concept we covered, and for that I feel like I am prepared to be an efficient and effective teacher of calculus. Thank you for helping me attain a greater understanding about these topics, topics I already thought I was knowledgeable in. (EL)

[8] Lea: As we continue our discussion of limits in class, it is clear that I struggle and have much to learn conceptually about limits and other concepts of calculus. Although I am thoroughly enjoying the challenges brought forth each week, at times I am very humbled in the realization that there is a lot that I still struggle and need to learn about these calculus concepts. For example, this week I learned that we can view a limit being a process or a product or both depending on context! (CD ∩ EL)

The results and the excerpts indicate that challenging teachers mathematically can be a good strategy to promote teacher development (enhanced learning). Although teachers may not realize every occasion where they experience a difficulty as an opportunity to learn, our results suggest that when they reflect on their learning and explicitly mention enhanced learning, they seem to have a tendency to think about the contexts in which they struggled with mathematics. Professional development environments which do not only put teachers in a teacher role reflecting on student thinking but also in a learner role where they genuinely struggle with content and reflect on their own mathematical thinking have the potential to provide rich learning opportunities for teachers. In addition, the existence of the theme EL as an emergent theme in the journals, which is elicited through the teachers' own voices and discourses, can also suggest that journal entries may be useful resources for teacher educators in assessing teacher learning or development in professional development situations. We promote the use of journals as potential teacher assessment tools because we believe they may provide context regarding teacher

thinking, which is a critical component when examining their development and also because of the connections we observed between the themes EL and FS as will be discussed next.

In teachers' journals, we identified 53 occurrences of the theme EL (as a component of SAL), 43 occurrences of the theme FS (as a component of SAT), and 21 occurrences of EL ∩ FS (as a component of SAL ∩ SAT). In about 40% of all the EL contexts, the teachers also mentioned pedagogical strategies they would use in the future and in about 49% of all the FS contexts, the teachers mentioned enhanced learning or understanding. Excerpt [7] provides an example for the theme EL. The following excerpts provide examples for the themes FS and EL ∩ FS.

[9] Ron: I liked in class how you asked the class to use one word to define function and then asked the class to use those words to form a definition. I feel that in teaching algebra II, I will use this approach since this could really get the students thinking. Students can take their previous knowledge of functions or any other concepts and reason through that when defining the concept. (FS)

[10] Sally: I can now say that when I start teaching functions next year, I will approach this topic completely different. I will now open my students up to a more discussion-based approach where we can openly look at the definition of function and talk about what makes something a function and what makes something not a function. This way they aren't trained to only know linear or quadratic functions. They won't consider a function just the "equation" or "graph" or "table" but know why the table represents a function or why the rule represents a function. My own learning and understanding of the topic in a deeper way helped me think about changing how I teach functions. (EL ∩ FS)

The results and the excerpts suggest that, although the teachers did not necessarily consider all the contexts in which they mentioned enhanced learning as opportunities to also reflect on the teaching strategies they would use in their future practice, almost half of their discussions about their future pedagogical strategies included teachers referring to their enhanced learning in the context of the course. This also suggests that changing teacher practice may be closely related to teachers changing their thinking (enhanced learning) about mathematical concepts.

Discussion

The results of the study demonstrate the complexity as well as the dynamic and situational nature of teacher knowledge, thinking, and development. A contextual analysis of teachers' (meta) discourses based on their authentic voices indicate that the teachers in our study did not separate their thinking about themselves or mathematics from their thinking about their students; similarly, they took different roles as teachers and learners in a given context. These findings challenge the existing trends in defining and measuring teacher knowledge, where such knowledge is often characterized as consisting of compartmentalized pieces (e.g., mathematical content knowledge, pedagogical knowledge, pedagogical content knowledge, mathematical knowledge for teaching). Contextually, these distinctions can be blurred, much more integrated, and complex. The emerging themes in the teachers' journals provide a cautionary tale regarding the potential dangers of providing an oversimplified picture of teacher thinking, knowledge and development (Beswick et al., 2012).

Schoenfeld (2007) highlights the importance of exploring which type(s) of knowledge that the measures assess and notes that "much needs to be done in fleshing out the relevant knowledge base to be tested and determining how well the items used actually reflect the desired competencies" (p. 204). Fauskanger (2015) found that the multiple-choice responses teachers

provide in the assessments of their mathematical knowledge for teaching may not reflect their knowledge as expressed in their open-ended, constructed responses and noted that a teacher could give an incorrect response to the test item but demonstrate conceptual understanding in the latter context. There may also be clashes between the researchers' and teachers' expectations and interpretations of the test items, their goal, and what they are supposed to measure (Fauskanger, 2015). Beswick et al. (2012) note that the precise way in which different types of teacher knowledge are conceived and "how aspects of such a conception beyond 'facts that are known' is incorporated" in such models is not clear (p. 133). It is important to note that, despite their problematization of the current approaches towards assessing teacher knowledge, researchers may still operate from only a cognitive view and may still provide attempts to "refine" or "expand" the characteristics of different types of teacher knowledge for better and more reliable assessment (e.g., Fauskanger, 2015; Beswick et al, 2012; Schoenfeld, 2007).

Characterization and assessment of teachers' knowledge or development based on knowledge compartmentalization and on the cognitive "knowledge-as-acquisition" metaphor (Sfard, 2001) can be problematic since this may not reflect the multi-faceted, dialogical, social, cultural, and contextual nature of teachers' thinking, knowledge and development, especially when viewed from sociocultural lenses which often characterize learning and development as occurring through enhanced participation in mathematical communities of practice (Lave & Wenger, 1991) through the "knowledge-as-participation" metaphor (Sfard, 2001). Our findings suggest that the theoretical frameworks that go beyond cognitive constructivism can be useful in our explorations and (re)interpretations of what we mean by teacher knowledge, thinking, and development and whether, and how, to assess them through standardized instruments. We believe sociocultural frameworks have a lot to offer to the field as we continue thinking about these critical issues, particularly if we want to put the voices of the teachers at the center of our discussions about teacher education in mathematics education research.

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