The Roles of Interest and Mathematical Beliefs in Preservice Teachers' Learning to Mentor Online

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Abstract. In the present paper, findings from study of a population of preservice teachers (PTs) at a large state university who worked with the Math Forum's *Online Mentoring Guide* (OMG, mathforum.org) are described. This is a group of elementary and middle-school preservice teachers who are motivated to learn and who self-report as having high levels of efficacy for mathematics, even though their mathematics abilities are weak. PTs responses to two forms of mentoring are analyzed and used as the basis for: (a) considering the motivational aspects of a productive disposition for working with mathematics, and (b) appreciating the constraints that lack of experience with and/or models of reform practice represent.

The present paper analyzes the process and describes the outcomes of two forms of mentoring used to support preservice teachers (PTs) as they learned to mentor their own students using the Math Forum's *Online Mentoring Guide* (OMG). PTs received either content-informed scaffolding, scaffolding that includes reference to the mathematics of the task; or performance feedback, information about whether they were providing appropriate comments and direction about what they should say. The content of the OMG is designed to support PTs to stretch the mathematical thinking of the elementary students whom they are assigned to mentor on work with nonroutine challenge problems.

The NRC (2001) report, *Adding it Up,* describes five interwoven and interdependent strands that apply to developing proficiency with mathematics and for teaching mathematics proficiently:

"• conceptual understanding—comprehension of mathematics concepts, operations, and relations
• procedural fluency—skill in carrying out procedures flexibly, accurately, efficiently, and appropriately
• strategic competence—ability to formulate, represent, and solve mathematical problems
• adaptive reasoning—capacity for logical though, reflection, explanation, and justification;
• productive disposition—habitual inclination to see mathematics as sensible, useful, and worthwhile, coupled with belief in diligence and one's own efficacy." (NRC, 2001, p. 5)

Cast in this way, mathematical proficiency and teaching for mathematical proficiency are integrally connected to the way in which learners engage mathematics: what they bring to problems to be worked and also what they need in order to work with these problems effectively. Productive disposition acknowledges the potentially important role of learner culture and socialization in the process of working with mathematics (DeCorte & Verschaffel, 2006; Lave, 1993; Schoenfeld, 1992).

Schoenfeld (1992) was one of the first to point out that the learners' mathematics culture impacts their sense of possibility about being learners of mathematics. This culture also informs the level of mathematics proficiency that can be obtained—including the extent to which prospective teachers are in a position to support their own pupils (Ma, 1999; RAND, 2002). In order to be motivated to teach the craft, PTs need to know what the craft includes and be supported to develop the productive disposition that practice of the craft requires. Productive disposition as it is described by the NRC (2001) only identifies a developmental endpoint, however—what is in place when learners are proficient. As the NRC report notes, what productive disposition involves is not well understood; nor are the means through which it might be supported to develop.

As findings from our prior work suggests, PTs can be motivated learners with high levels of efficacy for mathematics, and yet neither display the level of mathematics skills that studies of self-efficacy would predict (Bandura, 1986, 2006), nor engage in the reform practices that might be expected or hoped for. This may be a defensive response to their situation (see related discussion in Graham, 1994) and/or it may reflect the task demands of teacher education and mathematical problem solving as they know them (Renninger, Ray, Luft, & Newton, 2006).

Part of the difficulty may be that there is a discrepancy between what the tasks assigned require—what those practicing reform mathematics have defined the tasks as including— and the mathematics culture in which the learner is socialized. In prior work with PTs from the same university, two variables have emerged as likely indicators of productive disposition and may potentially impact PTs' readiness to work with mathematics: their interest for mathematics, and their mathematical beliefs or goals for problem solving (Renninger, et. al., 2006). These motivational variables appear to account for and influence the development of PTs' productive disposition.

Briefly, interest is here used to refer to the stored knowledge, value and feelings with which the PT re-engages mathematics; it refers to both the affective state and to the PT's predisposition to either return or not return work with mathematics (see Hidi & Renninger, 2006). The phase of learner interest has been found to positively impact attention, learning strategies, and goal setting (Hidi & Renninger, 2006), and in its most developed form is characterized by questioning and seeking answers to questions—behaviors suggesting that reengagement is perceived to be "sensible, useful, and worthwhile."

Mathematical beliefs, including goals for problem solving, refer to the PTs' "sense of mathematics as a discipline, and their relationship to it" (Schoenfeld, 1989). Mathematical beliefs refer to understandings (or misunderstandings) that PTs bring to their work with mathematics tasks, and are central to the way they define the mathematics tasks with which they work (DeCorte, Op-t-Eynde, & Verschaffel, 2002; DeCorte & Verschaffel, 2006). Such beliefs can be distinguished as either process-oriented or answer-oriented (Renninger, et. al., 2006). While getting a correct answer is an aim in problem solving, it is not the only aim.

The present study builds on prior findings that suggest a distinction between the between the performance-orientation of PTs' classroom mathematics and the more process-based focus of the Math Forum (Renninger, et. al., 2006). PTs' use of the mentoring they received was examined to determine whether this mentoring could support them to bridge this gap. The PTs were enrolled in a mathematical problem-solving course for preservice teachers. They uniformly had high levels of self-efficacy for mathematics but weak mathematics skills (determined based on their work with a set of problems that paralleled those given to the elementary students they were mentoring). The PTs differed in their interest and mathematical beliefs (identified using data from questionnaires distributed in-class prior to the students work with the Math Forum).

As part of their classwork, the PTs used the OMG, an asynchronous collaborative tool designed to help them learn how to scaffold the mathematical thinking of "live" elementary pupils working with nonroutine challenge problems on the Math Forum site. Lessons in the OMG include a 4-phase process of doing, reflecting/discussing, interacting with an experienced mentor, and synthesizing the experience of the previous three phases. After completing lessons in the OMG, PTs are assigned live elementary pupil submissions. They write a response to the pupil to whom they are assigned, and are scaffolded themselves by a Mentor to revise this response.

Inherent in the OMG lessons is the need to work with mathematics content and practice thinking mathematically. Prior studies of the OMG indicate that without mathematical content knowledge, PTs are not in a position to effectively facilitate the development of elementary students' mathematical thinking, nor are they in a position to independently further develop their own mathematical thinking (Renninger, et. al., 2006). Findings from these studies suggest that PTs can benefit from content-informed scaffolding—scaffolding that includes mathematics content and enables learners to make connections to, develop strategies, self-regulate, and be emotionally supported. Content-informed scaffolding includes fading feedback over time to encourage independence (Renninger, Ray, Luft, & Newton, 2005; West & Staub, 2003). Unaddressed in this work is how the content and format of content-informed scaffolding differs from the content and format of performance feedback, and how PTs respond to a mentor's suggestions based on these differences. Moreover, as a response to the NRC (2001) suggestion that productive disposition is a key strand in mathematical proficiency, the roles of PT interest and mathematical belief about mathematics were further investigated using discourse analysis (Gee, 1999) and grounded theory (Strauss & Corbin, 1990).

Methods

Descriptive questionnaires distributed prior to and following work with the OMG were used to assess PT interest for mathematics, mathematical beliefs, feelings of self-efficacy, and perceptions of the OMG. PTs' abilities to work with nonroutine challenge problems were assessed. All of the PTs' work with the OMG, including interactions with mentors about their work with students, was archived.

For the purposes of the present discussion, findings are reported from study of the PTs' work with the elementary students online and the scaffolding/feedback from their assigned mentors: 12 PTs, 6 of whom received content-informed scaffolding and 6 of whom received performance feedback. Three PTs in each group were identified as having more-developed interest and three were identified as having less-developed interest for mathematics.

Analyses of exchanges between the mentors and the PTs addressed: (a) whether PTs were more likely to make effective use of mentor suggestions if they were content-informed (see abbreviated example of content-informed scaffolding in Fig. 1), and (b) the role of PT interest and mathematical beliefs on readiness to work with mentor scaffolding. Analyses addressed both content and form of their interactions.

PT Response:

Hello Student 1!

Thank you for submitting your solution to this problem. You did a good job mathematically applying your strategy and finding the correct solution. Congrats!

There are only a few minor suggestions I could make to improve your solution's clarity.

I really enjoyed how clear your chart was, but there are some units missing. You remembered to label the total "miles" on the walking section of the chart, but there are no similar units for the miles that Zach rode the horse. Also, make sure you leave a space when writing fractions otherwise, 3 and 1/2 looks like 31/2.

Always try to reflect on your work and check it for accuracy. I look forward to reading your revision.

~PT 1

Coded Mentor Feedback:

The biggest suggestion I have is that instead of asking the student to give a reflection, try to encourage them to do so with questions.

Sometimes I ask questions like: Was this problem hard or easy for you? Why? Did you do anything to double-check your answer was correct? Did this answer surprise you? Did you think it would take longer or shorter to walk and ride 50 miles?

PT's Revision [due to space, only additions are noted]

Also, I liked that you added your mileage from both walking and riding together to see how many miles Zachary had traveled. What made you decide to do this? Could you explain this process to me and how it relates to the total miles Zach had to travel?

Now that you've done such a good job in answering the problem and explaining your solution, could you show me how you checked your answer to make sure it was right? What did you think of this problem? What was the hardest part? What made you decide to use your graph to help you explain?

Figure 1. Abbreviated Example of Content-Informed Scaffolding, PT and Mentor Exchange

Results

Three questions were addressed: How do the content and format of content-informed scaffolding differ from the content and format of performance feedback? How do PTs respond to suggestions based on differences in mentoring? What is the impact of PTs' interest and mathematical beliefs on their readiness to work with scaffolded feedback? Results for each are summarized. Tables are in the attached PowerPoint.

1. How do the content and format of content-informed scaffolding differ from the content and format of performance feedback?

PTs who received content-informed scaffolding had different patterns of responses to their mentor's suggestions than those who received performance feedback. Findings indicate that:

a. Mentors using content-informed scaffolding, encouraged PTs to:

- focus more on mathematics and math-specific pedagogy than mentors giving performance feedback, and were more varied in the content of the feedback they gave.
- vary the types of sentences they use, mixing statements, open-ended, and leading questions.
- focus on whether and how the elementary student was evidencing mathematical thinking to generate questions that would model reflection and encourage the elementary student to reflect in the process of answering questions.

b. Mentors using performance feedback were likely to lead PTs to:

- tell the elementary students what to do, and did not encourage PTs to ask leading questions.
- reply using statements.
- comment on the inadequacies of elementary student work, suggesting that the students were cheating or not doing their work.
- tell elementary students to reflect without providing a model.

2. How do PTs respond to suggestions based on differences in mentoring?

- PTs in both groups were predominantly told what to do and were likely to parrot the suggestions of the mentor.

- PTs receiving content-informed feedback had different responses to being told what to do and being asked questions. They were more likely to understand what they were told to do as demonstrated in their abilities to rephrase the mentor's suggestions in their own words. However, when working with mentor's questions, they were more likely to make mistakes.

- PTs who received performance feedback were not likely to demonstrate understanding of the comments they received by rephrasing mentor suggestions.

3. What is the impact of PTs' interest and mathematical beliefs on their readiness to work with scaffolded feedback?

- PTs' readiness to learn from content-informed scaffolding appears to be influenced by both their interest for mathematics and their mathematical beliefs about goals in problem solving. PTs with more developed interest for math *and* more process-oriented mathematical beliefs (rather than answer-oriented) were most likely to make use of scaffolding feedback generally.

- While some PTs had higher interest for math and were more likely to be process-oriented in their mathematical beliefs, interest and mathematical belief were not correlated.

- PTs with more interest for math were more likely to attempt to make use of scaffolding if they received content-informed scaffolding than if they received performance feedback. In addition, PTs with low interest for math made more use of scaffolding than PTs with high interest who received performance feedback.

- PTs with process oriented mathematical beliefs were more likely to attempt to make use of scaffolding if they received content-informed scaffolding than if they received performance feedback. However, PTs with process oriented mathematical beliefs did make use of performance feedback to a limited extent.

Discussion

Content-informed scaffolding is scaffolding that encourages reflection, identifies and stretches a learner's thinking, and considers the content of the mentoring to be mathematical problem solving rather than the problem at hand. Mentors who provided performance feedback, in contrast, gave task specific directions in one of two ways. They either told students this is an area of weakness: fix it, or they told students they could make their performance better by "doing the following" (e.g., reflect). Regardless of the type of mentoring PTs received, PTs were inclined to provide performance feedback to the elementary students.

Prior study of the PTs' classroom context suggests that the feedback they received in their classroom was primarily performance feedback (Renninger, et. al., 2006). Thus, it might be concluded that only the PTs in the content-informed scaffolding condition had a model or a vision of content-informed scaffolding. This discrepancy may account for what appears to be the tendency of PTs to ignore or misunderstand suggestions from content-informed scaffolding.

However, three trends emerge from these data suggesting the possibility that PTs such as these can be supported through content-informed scaffolding to provide content-informed scaffolding. First, PTs in the content-informed scaffolding group demonstrated understanding of mentor suggestions regardless of interest or problem-oriented mathematical beliefs more frequently than those in the performance-feedback group. Second, among PTs receiving content-informed scaffolding, higher interest PTs were more likely to make use of Mentor suggestions than lower interest PTs. Third, all PTs with process-oriented mathematical beliefs were more likely to make use of Mentor suggestions than those with accuracy-oriented mathematical beliefs. It appears that productive disposition conceptualized as including interest and problem-oriented mathematical beliefs may impact readiness for scaffolding.

Learning how to provide their own students with content-informed scaffolding should enable PTs to more effectively teach their craft. Both PTs' interest and their mathematical beliefs appear to influence their abilities to learn from mentoring about appropriate ways to scaffold their students. The scaffolding of PTs' work with elementary students, moreover, should involve questions, explanations, and math-specific content. This may be especially beneficial for PTs with well-developed interest and process-oriented mathematical beliefs. Findings further suggest that helping PTs to develop an interest for mathematics, and helping them to develop a more process-oriented stance towards mathematics may enable them to learn more effectively from mentoring.

As indicators of productive disposition for mathematics, interest and mathematical beliefs appears to influence whether the mathematically-informed scaffolding that the PTs received felt "sensible, useful and worthwhile"- such that they were able to begin to try to make use of suggestions and questions that they received from the mentors. Being able to work with the mentors' scaffolding enabled the PTs to stretch their mathematical understanding and begin looking like motivated learners.

Content-informed scaffolding appears to enable connections to mathematics in a way that performance-feedback does not. Such connections to mathematics and understanding appear to be enhanced by and/or are necessary for the development of productive disposition. PTs cannot be expected to immediately know how to provide content-informed scaffolding for their students if they have never experienced it before; nor without practice are they going to be positioned to develop the interest and mathematical beliefs that would allow them to engage mathematics productively. PTs appear to benefit from mentoring that allows them to experience reform practices. The coupling of reform practices with an outside-of-school context like the online environment provides an alternative to the performance-feedback that may have characterized their own experiences as students.

References

Bandura, A. (2006). Adolescent development from an agentic perspective. In F. Pajares & T. Urden (Eds.), *Self-efficacy beliefs of adolescents*. Greenwich, CT: Information Age Publishers.

Bandura, A., (1986). *Social foundations of thought and action.* Englewood Cliffs, NJ: Prentice-Hall.

DeCorte, E., & Verschaffel, L. (2006). Mathematical thinking and learning. In K. A. Renninger and I. E. Sigel (Eds.), *Child Psychology in Practice* (pp. 103-152). In W. Damon and R. Lerner (Gen. Eds.), *Handbook of Child Psychology*, 6^{th} ed. New York: John Wiley & Sons.

DeCorte, E., Op-t-Eynde, P., Verschaffel, L. (2002). "Knowing what to believe.": The relevance of students' mathematical beliefs for mathematics education. In B.K. Hofer & P. R. Pintrich (Eds.), *Personal epistemology: the psychology of beliefs about knowledge and knowing* (pp. 297-320). Mahwah, NJ: Lawrence Erlbaum.

Gee, J.P. (1999). *An introduction to discourse analysis: Theory and method.* London: Routledge.

Graham, S. (1994). Motivation in African Americans. *Review of Educational Research, 64* (1), 55-117.

Hidi, S. & Renninger, K. A. (2006). The four-phase model of interest development. *Educational Psychologist*, 41 (2), 111-127.

Lave, J. (1993). Understanding practice: Perspectives on activity and context. New York: Cambridge University Press.

Ma, L. (1999). *Knowing and teaching elementary school mathematics: Teachers' understanding of fundamental mathematics in China and the United States.* Mahwah, NJ: Lawrence Erlbaum.

National Research Council (NRC) (2001). *Adding it up: Helping children learn mathematics.* Washington, DC: National Academy Press.

RAND Mathematics Study Panel. (2002). *Mathematical proficiency for all students: Toward a strategic research and development program in mathematics education.* Santa Monica, CA: RAND.

Renninger, K.A., Ray, L., Luft, I., & Newton, E. (2006). A comprehension tool for mathematics? The Math Forum@Drexel's Online Mentoring Project. In S.A. Barab, K.E. Hay, & D.T. Hickey (Eds.), *Making a difference: Proceedings of the 7^{th} International Conference of the Learning Sciences.* Mahwah, NJ: Lawrence Erlbaum.

Renninger, K.A., Ray, L.S., Luft, I., & Newton, E.L. (2005). Coding online content-informed scaffolding of mathematical thinking. *New Ideas in Psychology 23*(2005): 152-156.

Strauss, A.L., & Corbin, J. (1990). *Basics of qualitative research: Grounded theory procedures and techniques*. Newbury Park, CA: Sage Publications.

West, L. & Staub, F. C. (2003). Content-focused coaching: Transforming mathematics lessons. Portsmouth, ME: Heinemann.