Capitalizing on Productive Norms to Support Teacher Learning

Laura R. Van Zoest
Western Michigan University

Shari L. Stockero
Michigan Technological University

We draw on research into the durability of sociomathematical and professional norms to make a case for attending to productive norms in teacher education experiences. We illustrate that productive norms have the potential to support teacher learning by (a) improving teachers' own mathematical understanding, particularly of specialized content knowledge; (b) supporting teachers to productively view and analyze classroom practice; (c) providing teachers an experiential basis for thinking about fostering productive norms in their classrooms; and (d) helping teachers to develop professional dispositions that support continued learning from practice. This work points to the importance of intentionally considering the norms cultivated in teacher education experiences, assessing their productivity, and strategically focusing on those that provide the best support for teacher learning.

Key words: Norms; Sociomathematical norms; Professional norms; Teacher learning; Teacher education

No teacher education experience, no matter how well designed or thorough, will be sufficient to prepare teachers for all that they will face in their future classrooms (Feiman-Nemser, 2001; Hiebert, Morris, Berk, & Jansen, 2007). This makes it critical that the limited time teacher educators have with teachers—particularly in methods classes—be used to lay a foundation that can be built on as they engage in the practice of teaching. One way to help do this is to intentionally cultivate patterns of behavior that support both short- and long-term teacher learning.

Knowing that the nature of a classroom's norms has been shown to significantly affect the learning that takes place within the classroom (e.g., Cobb, Wood, Yackel, & McNeal, 1992; Kazemi & Stipek, 2001), many mathematics teacher educators intentionally cultivate norms that create the kind of environment they feel will support teacher learning in their classrooms. Often, however, these norms focus on engaging teachers in the learning rather than on supporting the learning itself. An example of this would be focusing on the norm of having teachers explain their mathematical thinking about a given task, without being intentional about developing norms for using that thinking to support understanding of the mathematical concept(s) underlying the task. The result is a high level of participation that meets an important process goal, but may fall short of meeting important content goals (see, for example, Stockero & Van Zoest, 2011). In this sense, norms are often an underutilized teacher education tool.

Our work suggests that some norms have the potential to support teacher learning beyond that which takes place in a particular course or even an entire teacher education program (Van Zoest, Stockero, & Taylor, 2011). We draw on our research into the durability of professional and sociomathematical norms intentionally fostered in an initial mathematics methods course to make a case for the long-term benefits of attending to productive norms in teacher education experiences. In doing so, we highlight four ways in which productive norms have the potential to support teacher learning. We conclude with implications for teacher education and questions for future work.

Defining Norms

In classrooms, *norms* are regular patterns of behavior that affect the nature of the learning that occurs within them. In some cases, teachers (in our work, teacher educators) may intentionally foster specific patterns of behavior, but norms exist regardless of whether the teachers and students are aware of them (Bauersfeld, Krummheuer, & Voigt, 1988; Voigt, 1998).

Yackel and Cobb (1996) made a key distinction between *social* and *sociomathematical* norms. *Social* norms are regular patterns of behavior that can apply to any subject area and, thus, are not unique to mathematics classrooms, while *sociomathematical* norms are specific to mathematical activity. Seago, Mumme, and Branca (2004) introduced the term *professional norms* to indicate standard patterns of behavior unique to learning about teaching.

These different types of norms are often related. For example, the social norm of *supporting one's answer with an explanation* creates the need for the sociomathematical norm of *what counts as a mathematical explanation* and is related to the professional norm of *backing up* *claims about teaching and learning*. *Supporting one's answer with an explanation* is a social norm because it is not unique to a mathematics classroom; it could also be a norm for interacting in an English, science, or history class. *What counts as a mathematical explanation* is unique to mathematics, although the norm could look different in different classrooms. For example, in one classroom, saying what one did might suffice, while in another, the explanation might require providing mathematical justification for what one did.

The majority of work with sociomathematical norms has been in the context of learning what Ball, Thames, and Phelps (2008) described in their *Domains of Mathematical Knowledge for Teaching* as *common content knowledge*: "mathematical knowledge and skill used in settings other than teaching" (p. 399). Our work with teachers, however, also focuses on the development of *specialized content knowledge*: "mathematical knowledge and skill unique to teaching" (Ball et al., 2008, p. 400). Even though the level of the activity is different, we have found that the sociomathematical norms themselves are similar. For example, while the students' focus would be on providing a mathematical explanation for their solution, the teacher's focus might also include determining whether a student's explanation is sufficient and mathematically accurate.

Backing up claims about teaching and learning is a professional norm because it is specialized to the work of learning about teaching. Similar to the sociomathematical norm *what counts as a mathematical explanation,* this professional norm also varies across learning contexts. In one teacher learning setting, it might include initial impressions and simple reflections, while in another, teachers might substantiate claims about teaching and learning using classroom-based evidence, including student work, dialog, and other artifacts of practice.

Research on norms in mathematics education has at its core the intent to develop inquiry-based classrooms that engage learners in worthwhile mathematics (e.g., National Council of Teachers of Mathematics [NCTM], 2000). Thus, research has focused on how existing norms provide obstacles to this goal, what norms might support meeting the goal, and how these supportive norms can be developed in classrooms. In general, it has been established that intentionally fostering productive norms, particularly productive sociomathematical norms, can improve mathematics learning at any level—for example, elementary (Mottier Lopez & Allah, 2007), secondary (McClain, 2009), university (Stylianou & Blanton, 2002), teacher preparation (McNeal & Simon, 2000), and professional development (Clark, Moore, & Carlson, 2008). Of particular relevance to teacher education is the finding that an investment in developing these productive norms in methods courses can support teachers' future learning (Van Zoest et al., 2011). Drawing on this growing body of research on norms, we use the adjective *productive* to distinguish norms that support student learning from other norms that may have no effect on learning (e.g., the students always write in pencil) or may actually undermine it (e.g., the teacher does all the thinking during lessons).

In this article, we provide more detailed examples of two productive norms—one sociomathematical and one professional—that we use to illustrate the ideas in the remainder of the paper. The examples are drawn from a study investigating the extent to which prospective teachers' experiences and learning in an initial secondary school mathematics methods course have long-term effects on their professional practice (e.g., Van Zoest et al., 2011). Before continuing, we give an overview of both the course and the study.

The Course

The initial methods course was the first of three courses devoted to the teaching of secondary school mathematics in an NCTM (2000) *Standards*-based teacher preparation program that focused on teaching mathematics for student understanding. The first course focused on teaching at the middle school level, with an emphasis on analyzing and understanding student thinking and implementing instructional practices with small groups of students. The second course focused on using technology to support mathematics instruction, and the third focused on teaching at the high school level, with an emphasis on unit planning and whole-class instruction.

We approached both the development of the initial mathematics methods course and the research from a situated perspective (e.g., Borko et al., 2000). That is, we generated learning situations that were similar to those in which we intended the learning to be used, and we studied the way in which participants interacted in them. In the context of the initial methods course, we used the professional development curriculum *Learning and Teaching Linear Functions (LTLF): Video Cases for Mathematics Professional Development, 6-10* (Seago et al., 2004) to help prospective teachers learn to analyze student thinking and teacher decisions during classroom interactions, as well as the relationship between them. Each of the eight LTLF video modules began with the prospective teachers individually solving a mathematics problem, after which they shared and discussed their solution strategies as a group. The prospective teachers then viewed video clips of school students sharing their thinking about the same problem, and analyzed and discussed the student thinking and teacher actions seen in the video. This is similar to the type of ongoing analysis in which teachers need to engage in order to make sense of and build on student thinking during instruction. In addition, the prospective teachers had an opportunity to “try out” the ideas they were learning with small groups of middle school students. They did so by planning for and implementing tasks from the LTLF modules, after which they reflected on students’ thinking and ways in which they as the teacher either supported or inhibited that thinking. More details about the structure and content of the course can be found in Van Zoest and Stockero (2008a, 2008b, 2009) and Van Zoest, Stockero, and Edson (2010).

In the discussions of the LTLF video cases and of the prospective teachers’ work with middle school students in the initial course, the instructors focused on cultivating professional and sociomathematical norms embedded in the LTLF curriculum (see Table 1). These norms were intended to support the development of professional skills and dispositions necessary for teachers to productively study practice with their colleagues. Although we were intentional about cultivating these norms, at the time of the study we used what Bernstein (2004) called an *invisible pedagogy* in that neither the norms themselves, nor the moves we made to cultivate them, were made explicit to the teachers.[1] When the teachers shared their mathematical thinking, for example, we pushed them to provide a mathematical justification, rather than just report the procedure they had used, but did not explicitly discuss that we were cultivating justification as a desired pattern of behavior. Research on the learning outcomes of the course before and after incorporating the LTLF curriculum (Stockero, 2008a; 2008b) documented, among other things, evidence of prospective teachers engaging in the norms embedded in the LTLF curriculum—norms that had not been evident among prospective teachers in the course prior to incorporating the curriculum.

The Study

The study looked at the long-term effects of teacher experiences in the previously described initial methods course on their professional practice. The participants were 11 prospective secondary school mathematics teachers (PTs) enrolled in the third methods course, and 16 beginning secondary school mathematics teachers (BTs) who were graduates of our program with fewer than four years of teaching experience. The PTs had been enrolled in the initial methods course in four different semesters, with 1 to 4 enrolled in the course during any given semester; the BTs had been enrolled in five different semesters, with 2 to 4 concurrently enrolled. Both authors taught and designed the course, but approximately half of each participant group had taken it from other instructors. The other instructors were mentored by the first author, used the same curriculum, and cultivated the same norms. Including both the PTs and BTs in the study enabled us to look at the extent to which documented learning outcomes persisted at different points in time.

To understand how the initial methods course activities may have supported long-term teacher learning, we separately engaged the PT and the BT groups in activities centered on the Counting Cubes Problem[2] in Figure 1.

Table 1
Sociomathematical and Professional Norms in the LTLF Curriculum (*Seago et al. 2004*)

Sociomathematical norms	Professional norms
Naming, labeling, distinguishing, and comparing mathematical ideas [*naming and comparing*]	Listening to and making sense of or building on others’ ideas [*listening*]
Using mathematical explanations that consist of a mathematical argument, not simply a procedural description or summary [*mathematical argument*]	Adopting a tentative stance toward practice—wondering versus certainty [*tentative stance*]
Raising questions that are related to the mathematics and push on understanding of one another’s mathematical reasoning [*pushing understanding*]	Backing up claims with evidence and providing reasoning [*evidence*]
	Talking with respect yet engaging in critical analysis of teachers and students portrayed on the video [*critical yet respectful*]

1 As a result of what we have learned from our research program, we now make more explicit to teachers the specific norms that we are cultivating in our work with them. This allows the productive norms that they are experiencing to become a topic of discussion, adding another layer of potential learning. By doing this, we are able to more fully take advantage of the spectrum of ways that norms can support teacher learning.

2 The Counting Cubes Problem and the accompanying video are from the Turning to the Evidence project (see Seago & Goldsmith, 2005).

Study the sequence of cube buildings below. Assuming the sequence continues in the same way, how many cubes will there be in the 4th building? The 17th building? The *n*th building?

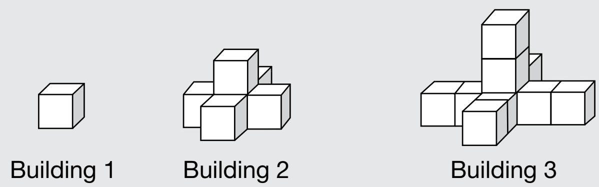

Figure 1. **Counting Cubes Problem solved by the teachers in the study and the students in the video they watched.**

These activities were similar to those they had participated in during the initial methods course. The PTs engaged in the activities during one 80-minute class session in their third (and final) methods course of the program; the BTs engaged in the activities during a 1-day professional development session held as part of the study. Neither of the two other mathematics teacher education courses in the program used video analysis as an instructional tool. Beyond the expectation in the second course that written responses to mathematics problems were to include detailed explanations of their thinking and the expectation in the third methods course that prospective teachers listen to each other as they discuss ideas about teaching, there was no evidence to suggest that the norms cultivated through the LTLF curriculum (see Table 1) had been specifically addressed in the remainder of the mathematics teacher education courses. None of the BTs' professional development experiences since graduation (as indicated in an online survey) had used video case analysis as an instructional tool or been focused specifically on mathematics instruction. Thus, there was no evidence to suggest that any of the participants had engaged in discussions grounded in representations of practice where norms such as those in Table 1 were intentionally cultivated since they had taken their initial methods course.

To gain insight into the participants' individual thinking and their interactions in the group, data for the study included both participants' written work and recordings of the group discussions. The individual work included solutions to the mathematical task, predictions about potential student solutions, and reflections on the video cases and on the session overall. The writing prompts and those given by the authors in their role as session facilitators were carefully worded and intentionally left open-ended to avoid directing the participants' thinking or prompting them to consider norms. For example, participants were asked, "What did you notice in this segment about students' thinking?" and "What did you notice about the teacher's questions, contributions, actions, or role in instruction?"

Transcripts of the recordings and the written work were coded independently by at least two researchers for examples and counterexamples of each targeted norm. Counterexamples were important to document because they allowed us to determine whether a behavior that violated a targeted norm was recognized and addressed by other group members. The research group met throughout the process to verify that the coding was consistent and to resolve any differences.

The researchers then looked across the coding to determine what behaviors were normative for the group. This analysis involved developing multiple charts that cross-referenced examples and counterexamples for each targeted behavior by participant and data source. These charts were used to determine the number of participants who engaged in each target behavior and the number of behaviors in which each participant engaged. This allowed the researchers to draw conclusions about whether each behavior was normative for the group. Note that classifying a behavior as a group norm did not mean that everyone engaged in it all the time, but rather that it appeared to be the standard pattern of behavior to which the group aspired. Thus, a behavior was classified as normative if most participants engaged in the behavior when appropriate to do so, and when they did not, the behavior was corrected or addressed by another member of the group.

For more details on the study methodology and results, including individual and group analyses of the PTs and BTs, see Van Zoest et al. (2011). Henceforth, the PTs and BTs collectively will be referred to as "the teachers." In the following section, we provide examples of two productive norms that will be used to illustrate the ideas in the remainder of the article.

Examples of Productive Norms

Mathematical Argument

The sociomathematical norm of *using mathematical explanations that consist of a mathematical argument, not simply a procedural description or summary* [referred to as *mathematical argument*] (Seago et al., 2004) has been found to create rich opportunities for students to engage as mathematical thinkers (see Yackel, 2002, for an analysis of argumentation across grade levels). Because proof and justification are central to the discipline of mathematics, this norm is particularly important to mathematics instruction that focuses on sense-making and developing a deep understanding of mathematical ideas—qualities advocated by the NCTM *Standards* (e.g., 2000) and the *Common Core State Standards for Mathematics* (CCSSI, 2010). We turn now to examples from our study to explore what counts as a mathematical argument.

We begin by looking at some attempts to provide mathematical arguments for the Counting Cubes Problem (Figure 1) that were identified as counterexamples to the norm because they lacked adequate mathematical justification. For example, in response to the prompt "show how you arrived at your solution," one teacher wrote about his expression, $5x - 4$, "I counted the differences, noticed that the pattern increased by 5 each time, so I chose $5x$. Then I used mathematical thinking to decide on what to add or subtract." Similarly, another teacher explained the constant term negative four as follows: "[B]uilding One started with one. That means five less would have been negative four. Building Zero would have been negative four cubes. And that's where the negative four comes from." Both of these cases were identified as counterexamples to the *mathematical argument* norm because the responses simply summarized the process used to arrive at a final expression, rather than justifying why the final expression made sense mathematically.

The following two responses exhibit the norm, even though the explanations left room for improvement. To justify her expression, $5n - 4$, a teacher wrote, "My solution accommodates my visualization of 5 blocks adding every [time] to the original cube: one cube spreading out at its arms." While this teacher justified the first term of the expression, $5n$, she made no attempt to explain the negative four, rendering her argument incomplete. Another teacher provided a stronger explanation of his expression for the total number of cubes in the nth figure, $n + 4(n - 1)$: "The solution relates to the picture by the single n as the center [column] growth, the 4 is the number of [horizontal] legs and the $(n - 1)$ is because each leg contains 1 less block than the figure number." Although his language was not precise (i.e., he identified n as the center column growth, instead of the number of blocks in the center column), he justified each part of the expression in relation to the diagram provided with the task. It is this justification based on mathematical ideas that is the intent of the *mathematical argument* norm.

The above examples were in the realm of *common content knowledge* (Ball et al., 2008) because they involved the teachers solving a basic algebra task. We turn now to an example that draws on *specialized content knowledge*. In this example teachers were asked to predict how students might think about the Counting Cubes Problem, drawing on specialized content knowledge because predicting others' thinking is unique to teaching. In this context, argumentation was used when teachers went beyond predicting correct or incorrect expressions that students might produce, to thinking about how students might visualize and make sense of the task. One teacher, for example, engaged in the norm of *mathematical argument* when she described one way that students might think about the task that would result in an expression of $5n - 4$:

> **So one of the ways that I thought of [how] a student might think of [the] arm length, if you think about the arm length as being the same as the building number, then [in the five arms] you would know you counted the middle block four times too many. So you could multiply the building number by five, but then subtract four.**

In this case, the explicit language and description that the teacher used in sharing her prediction of student thinking went beyond a procedural account of what students might do, to a justification of why the students' thinking would mathematically make sense.

Evidence

The professional norm of *backing up claims with evidence and providing reasoning* [referred to as *evidence*] (Seago et al., 2004) supports teachers in making sense of classroom events and drawing conclusions that will help them improve their practice. Rather than responding to events based on emotions or initial reactions that may not accurately reflect the underlying issues, this norm helps teachers learn to use classroom-based evidence to make decisions that support the development of students' mathematical understanding. In our study, this behavior was exhibited in two different ways: (a) when participants quoted the video transcript verbatim (or nearly so), and (b) when participants referenced specific line numbers from the transcript to support an argument. The transcript excerpt in Figure 2 illustrates these two ways.

During the professional development session, the facilitator prompted the following discussion by noting a teacher's observation that the students in the video were making sense of several different expressions and asking whether the participants had any observations regarding the connections being made among these expressions.

Teacher 1: Well, I think the teacher probably kicked it off when he said, "Are they the same or are they different?" . . . It's like the line, "Could someone think they can show that they're the same or different?" and Zach raises his hand. So, Zach is kind of prompted to go up to the board and say, "Hey, these are, you just have to use this distributive property thing."

Teacher 2: [The teacher] also asked, on line 32, um, to Cassie, "How is yours different or the same as what Arden and Yoshio did?" And that was one of the things I think [another teacher in her small group] pointed out, for me, maybe that Cassie didn't quite understand it. [Cassie] said, "The only thing that was different was that we subtracted and he added.'' And that really didn't—

Teacher 1: That doesn't make a lot of sense.

Teacher 2: It doesn't make a lot of sense. I mean, it makes it, maybe visually it makes sense, okay they have an adding sign and we have a subtracting sign, but it didn't get to really the root of what's different about it.

Teacher 3: For me, I thought 46 through 49 was like a big moment, where [Zach's] like, "I think what Arden is trying to do" and he nailed it, he said, "Arden's calling it, they're just renaming their variables."

***Figure* 2. Excerpt from discussion during the professional development session.**

Teacher 1 quoted the transcript verbatim ("It's like the line, 'Could someone think they can show that they're the same or different?'") to support her idea that the teacher's goal was to help the class realize that two of the expressions, $5n - 4$ and $1 + 5(n - 1)$, were the same, just written in a different way. Teacher 2 referenced a line number to further support the claim that the classroom teacher was trying to get the students to compare different mathematical expressions. Teacher 3 used line numbers to provide a rationale for his thought that Zach was the one who articulated what each group's expressions were representing [one group used zero as their first building number and the other group used one, resulting in different expressions]. In this excerpt, the teachers were spontaneously engaging with the *evidence* norm by using quotes from the transcript and line numbers to support their thinking. Rather than making unfounded claims or providing an emotional reaction to an idea under discussion, the teachers were engaged in analyzing and making sense of what was actually being said by the students and teacher in the video and what it meant in relation to student understanding of the mathematics. It is this emphasis on attending to aspects of classroom interactions that can be used to learn from teaching that makes the *evidence* norm productive.

In the following section, we use these two examples of productive norms—*mathematical argument* and *evidence*—to illustrate our findings about how cultivating productive norms in methods courses can support teacher learning (e.g., Van Zoest et al., 2011).

Reasons for Cultivating Productive Norms

Many teacher educators are aware of norms and take steps to cultivate specific norms in their teacher education contexts, yet fall short of taking full advantage of the different types of learning that norms might support. We have found that *productive norms* have the potential to support teacher learning by (a) improving teachers' own mathematical understanding, particularly the specialized content knowledge needed for teaching; (b) supporting teachers in learning to view and analyze classroom practice in productive ways; (c) providing teachers an experiential basis for thinking about fostering productive norms in their classrooms; and (d) helping teachers to develop professional dispositions that support continued learning from practice.

In the following sections, we describe, and draw on our work to illustrate, each of these reasons for cultivating productive norms in teacher education. Although we discuss the reasons separately to highlight the contributions each makes, we see them as interacting with one another in supportive ways to achieve the goal of improved classroom practice.

Improving Teachers' Mathematical Understanding

The reason for cultivating productive norms most commonly discussed in the literature (e.g., Grant, Lo, & Flowers, 2007; McNeal & Simon, 2000) is to help teachers improve their own mathematical understanding. Through cultivating specific sociomathematical norms, such as *mathematical argument*, learners are pushed to make sense of mathematical ideas they may previously have only superficially understood.

The examples in the *mathematical argument* section illustrate how cultivating this norm helps teachers develop a deeper understanding of mathematics. When teachers engage in this norm, they go beyond knowing how to get an answer, to understanding why the answer makes sense mathematically and what mathematical ideas underlie the solution process. Consider, for example, the subtle difference between the statements, "I counted the differences, noticed that the pattern increased by 5 each time, so I chose $5x$" and "My solution [$5n - 4$] accommodates my visualization of 5 blocks adding every [time] to the original cube: one cube spreading out at its arms." The first statement asserts *that* the number of blocks increases by 5 each time, while the second explains *why* this is the case. The second, we argue, is more productive in that the ability to provide this kind of justification is an important component of the *common content knowledge* teachers are being asked to help their students develop, knowledge that goes beyond learning procedures to making sense of mathematics (e.g., CCSSI, 2010; NCTM, 2000).

In the methods course, we specifically engaged teachers in doing mathematics and providing justification to prepare them to engage with the LTLF videos. We have found, however, that cultivating the *mathematical argument* norm also supports teachers in developing *specialized content knowledge*, as it helps them learn to recognize what student explanations might count as a mathematical argument. We see this in the following excerpt, in which a teacher discussed how students in the video were able to justify a part of a mathematical expression that the teachers themselves were unable to justify in their own discussion.

> **I couldn't figure out how to describe where you take away the four. 'Cause I did it like [another teacher] did it, with the four—well, I did it in a table, but then I also saw the $4(n - 1) + n$. I was like, "Oh, well, that's how you get your minus four." But I like how this [student explanation] actually shows this is how you take away the four.**

In this excerpt, the teacher provides some indication that hearing the student's mathematical argument helped her better understand the mathematics in the task. If the *mathematical argument* norm had not been established, it is quite possible that this teacher would not have been uncomfortable with her own inability to provide an argument, and thus, would not have noted the significance of the argument the student provided. Thus, cultivating the *mathematical argument* norm appears to have supported this teacher's own mathematical learning, as well as her ability to productively analyze practice—a second way that norms can support teacher learning.

Viewing and Analyzing Classroom Practice

The cultivation of productive sociomathematical and professional norms, such as *mathematical argument* and *evidence*, also supports teachers in learning to view and analyze classroom practice in productive ways, including making sense of student ideas, becoming more tentative about initial analyses, and seeking evidence to support conclusions about student learning (Stockero, 2008a, 2008b).

The sociomathematical norm of *mathematical argument* prepares teachers to both recognize when students provide a sound mathematical argument (as seen in the previous excerpt) and notice when a student's explanation may indicate an incomplete understanding of the mathematics. For instance, a teacher noted that two students in the video "had the slope figured out by their reasoning of the picture and found the intercept by fitting their line into their data. They didn't have conceptual reasoning based on the picture [for] why you should subtract 4." In this case, the teacher recognized that the student seemed to have a sound understanding of slope, but may not have fully understood the meaning of the intercept in this problem context. This analysis of practice is markedly different from that in which teachers make judgments about students' understanding based on whether or not their answer is correct.

Cultivating the *mathematical argument* norm in their initial methods course also supported the teachers in our study in noticing whether the norm seemed to be in place in the classroom they analyzed in the video. For instance, one teacher noted:

> **[I]t's very important that students were expected to explain their work to their peers. This verbal explanation—added onto their written work—makes misconceptions more obvious and also lets other students hear explanations [of] classmates. Also, [it] shows if they really understand what they did.**

Here, the teacher noticed that the norm of *mathematical argument* was in place and articulated the value of this norm for its ability to support teaching and learning. This type of noticing has the potential to support teachers in continuing to learn from practice, as it helps them to make sense of how mathematical understanding can be supported in a classroom.

The professional norm of *evidence* also supported the teachers in productively viewing and analyzing practice. Recall that this norm was exhibited when teachers used video transcript line numbers or quotes to support their analysis of practice. This use of evidence can be seen throughout the excerpt in Figure 2. The resulting dialogue is very different from that which occurs when analyses of practice are based on recollection and emotion—a common occurrence in teacher education settings. When the *evidence* norm is in place, teachers are able to engage in grounded analysis and reflection in which they learn to make sense of what is actually being said by the students or teacher. This helps teachers develop listening skills that are critical to student-centered instruction and learn to focus on key aspects of the interactions that matter to student learning—professional habits that lay a foundation for continued learning from practice. In addition, despite differences in the reflection time and type of evidence available, there is some indication that dispositions developed through teacher education experiences focused on analyzing artifacts of practice transfer to classroom instruction (Sherin & van Es, 2009). Thus, cultivating the disposition of using evidence to ground analyses of practice holds promise for supporting teachers in making evidence-based in-the-moment decisions during instruction.

Fostering Productive Classroom Norms

Since many teachers have not learned mathematics in student-centered classrooms where ideas were shared and discussed, a third reason for cultivating norms is to provide teachers with an experiential basis for thinking about fostering productive norms in their own classrooms. Teachers' ability to engage in and recognize the importance of productive norms for supporting mathematical learning is an important first step in cultivating these norms in their own mathematics classrooms.

Examples in previous sections illustrated how cultivating the sociomathematical norm of *mathematical argument* helped teachers consider what a sound mathematical argument might look like in a given instructional situation. However, even when the kind of argument a teacher might push for is clear, orchestrating productive discussions in which students justify and make connections among their mathematical ideas is still challenging (e.g., Smith & Stein, 2011). The professional norm of *evidence* helps teachers analyze specific teacher moves that might foster norms that support productive mathematical discussion and argumentation in their own classroom.

One teacher, for instance, noticed that "[the teacher] did not tell students, he asked students questions that focused them to specific aspects of the work (lines 32, 35, and 61)." Although this teacher did not list specific questions, an analysis of the transcript reveals that he was noticing that the teacher in the video asked questions that included: "How is yours different or the same as what Arden and Yoshio did?" (line 32), "Does that make it different? Is it the same, or what?" (line 35), and "Is your expression the same as any of the other ones? Because they all look different somehow. They have different numbers in them. Are any of them like equivalent or the same?" (line 61). In each case, the teacher noticed specific teacher moves that focused students on listening to and making sense of one another's ideas and on comparing and making connections among them—all productive norms in a mathematics classroom focused on using student thinking to develop mathematical understanding. Analyzing how other teachers cultivate productive norms provides teachers a foundation for developing ideas about cultivating such norms in their own classrooms.

Developing a Professional Disposition

A fourth reason for cultivating productive norms is to help teachers to develop professional dispositions that support continued learning from practice. This may be the most powerful way to think about taking full advantage of norms in teacher education, as it has the potential to promote learning that will lead to what Franke, Carpenter, Fennema, Ansell, and Behrend (1998) called *self-sustaining generative change*—change that will provide a basis for continued growth long past the end of the teacher education experience.

The discussion in the previous sections provides evidence of ways that norms might support this continued teacher learning. The examples illustrate how cultivating productive norms helped the teachers in our study develop a disposition of: (a) making sense of mathematics and expecting students to do the same; (b) carefully listening to and making sense of student ideas; (c) engaging in grounded analysis of practice; and (d) considering teacher moves that might allow them to cultivate productive norms in their own classrooms. These dispositions will allow them to continue to learn from practice, as together they form the foundation of a reflective practitioner—one who has the ability and propensity to engage in critical analysis and reflection, consider alternatives, and make connections between theory and practice.

We have some evidence that the teachers in our study who had classrooms of their own were, in fact, building on the dispositions developed in the methods course to support their instruction. For example, one teacher compared the mathematical arguments his own students might give to those given by the students in the video:

> **[In my classroom] I always like to hear somebody explain how to do it verbally, which I think was what really happened really well on the clip, because definitely being able to explain your reasoning and even teach somebody else how to do it is on a level of Bloom's Taxonomy that, you know, not only do they know it, but they can comprehend it and explain it as well.**

In this explanation, the teacher articulates the value of having students provide mathematical justifications for their solutions, rather than simply describing the procedures they used. This suggests that he was attempting to develop the *mathematical argument* norm in his own classroom. In general, the norm of *mathematical argument* supported the development of a professional disposition that led teachers to expect a mathematical justification for ideas. That is, they were not satisfied with students simply replicating what was said in a book or in a curriculum standard, but rather expected them to use reasoning and argumentation to help make sense of the mathematics being taught.

The use of evidence to support analyses of practice provides a means of connecting specific instances of practice with general theories about teaching and learning; these connections then serve as a basis for ongoing learning. One striking difference that we found between the PTs and BTs in our study was in whether the claims they used evidence to support were generalizations or specific claims. For example, the statement "[the teacher] did not tell students, he asked students questions that focused them to specific aspects of the work (lines 32, 35, and 61)" uses evidence to support a generalization about the teacher's actions, while the statement "I didn't really like how he funneled the question on line 85. It was a yes or no question" focuses only a specific instance.

In general, the PT teachers in our study were much more likely to invoke evidence to support specific observations, while the BTs' use of evidence was more balanced between supporting generalizations and supporting specific claims. We conjecture that the PTs may have been more cognizant of providing evidence since they were still in a university setting and not as far removed from the context in which this more academically oriented norm had been introduced, and thus did so more frequently in superficial ways. The fact that the BTs provided evidence in more meaningful ways suggests that the more significant aspect of this professional norm endures over time; that is, this norm supports teachers in using evidence to make sense of classroom events and draw conclusions that will help them to continue to improve their practice.

Implications for Teacher Education and Questions for Future Work

We have identified how productive norms can support teacher learning by (a) improving teachers' own mathematical understanding, particularly the specialized content knowledge needed for teaching; (b) supporting teachers in learning to view and analyze classroom practice in productive ways; (c) providing teachers an experiential basis for thinking about fostering productive norms in their classrooms; and (d) helping teachers to develop professional dispositions that support continued learning from practice. We highlighted the fact that although social norms, such as explaining one's thinking, are important, they fall short of supporting teacher learning unless they are coupled with sociomathematical and professional norms that support learning specific to mathematics teaching. As a result, mathematics teacher educators need to carefully consider the potential of focusing on a range of norms—social, sociomathematical, and professional—in terms of the many ways that such a focus supports both short- and long-term teacher learning.

Our work speaks to the importance of intentionally considering the norms cultivated in teacher education experiences. This includes identifying those that are productive—such as *mathematical argument* and *evidence*—and systematically integrating them into our curricula. In fact, this work has provided evidence that not only can productive norms be fostered and used to support teacher learning in a particular teacher education course (e.g., Stockero, 2008b), they can also support longer-term learning (Van Zoest et al., 2011). The finding that intentionally developing productive sociomathematical and professional norms early in a teacher education program can contribute to teachers' continued learning from practice is particularly encouraging given the benefits of *self-sustaining generative change* (Franke et al., 1998) to ongoing teacher development.

Fully capitalizing on the potential of productive norms to support teacher learning requires further work. First, we need to know what norms support meeting our teacher education learning goals. The norms discussed here—*mathematical argument* and *evidence*—have been shown to be productive and can be cultivated in teacher education experiences with confidence. In our work, we have found other norms—such as the sociomathematical norm of *naming, labeling, distinguishing, and comparing mathematical ideas*, and the professional norm of *listening to and making sense of and building on others' ideas*—to also be productive (Van Zoest et al., 2011). As other teacher educators systematically analyze the productivity of additional norms, we encourage them to share their findings with the mathematics teacher education community.

Second, we need to know more about the sequencing of norms. Focusing on developing a large number of norms at the same time is not practical and risks diluting the benefits of the most productive norms. Knowing which norms are foundational and which ones are better introduced further into the program would be very helpful.

Finally, our experience suggests that additional learning can occur from discussions with teachers about why we are intentionally cultivating specific norms. As discussed previously, at the time of the study we were using an *invisible pedagogy* (Bernstein, 2004), in that the norms that we intended to establish were not made explicit to the teachers. After completing the study, however, we conjectured that it would have been beneficial to be explicit about the norms we were cultivating, the reasons we felt these norms would be productive, and the moves we were making to cultivate them. More work is needed to verify this conjecture and, if it is found to be true, to determine effective ways to make the use of productive norms more visible. Doing so may allow the cultivation of norms to affect teachers' learning in even more powerful ways.

Although there is more work to be done to take advantage of the opportunity that cultivating productive norms provide for meeting the challenging task of preparing mathematics teachers, there is enough information to get started now. As you think through your teacher education work, we encourage you to think about the norms that are currently in place, assess their productivity, and consider augmenting or replacing them with norms that have been demonstrated to be productive—such as *mathematical argument* and *evidence*. Doing so will lay a foundation that teachers can build on as they engage in the practice of teaching. Developing reflective teachers who can learn from their practice is essential for meeting the ambitious goals of mathematics teaching called for by NCTM (e.g., 2000).

References

Ball, D. L., Thames, M. H., & Phelps, G. (2008). Content knowledge for teaching: What makes it special? *Journal of Teacher Education, 59*, 389–407.

Bauersfeld, H., Krummheuer, G., & Voigt, J. (1988). Interactional theory of learning and teaching mathematics. In H. G. Steiner & A. Vermandel (Eds.), *Foundations and methodology of the discipline of mathematics education* (pp. 174–188). Antwerp, Belgium: Theory of Mathematics Education (TME) Conference.

Bernstein, B. (2004). Social class and pedagogic practice. In S. J. Ball (Ed.), *The Routledge Falmer reader in sociology of education* (pp. 196–217). London: Routledge.

Borko, H., Peressini, D., Romangnano, L., Knuth, E., Willis-Yorker, C., Wooley, C., . . . Masarik, K. (2000). Teacher education does matter: A situative view of learning to teach secondary mathematics. *Educational Psychologist, 35*(3), 147–217.

Clark, P. G., Moore, K. C., & Carlson, M. P. (2008). Documenting the emergence of "speaking with meaning" as a sociomathematical norm in professional learning community discourse. *Journal of Mathematical Behavior, 27*, 297–310.

Cobb, P., Wood, T., Yackel, E., & McNeal, B. (1992). Characteristics of classroom mathematics traditions: An interactional analysis. *American Educational Research Journal, 29*(3), 573–604.

Common Core State Standards Initiative (CCSSI). (2010). *Common core state standards for mathematics*. Retrieved from http://www.corestandards.org/the-standards/mathematics

Feiman-Nemser, S. (2001). From preparation to practice: Designing a continuum to strengthen and sustain teaching. *Teachers College Record, 103*(6), 1013–1055.

Franke, M. L., Carpenter, T., Fennema, E., Ansell, E., & Behrend, J. (1998). Understanding teachers' self-sustaining, generative change in the context of professional development. *Teaching and Teacher Education, 14*(1), 67–80.

Grant, T. J., Lo, J.-J., & Flowers, J. (2007). Shaping prospective teachers' justifications for computation: Challenges and opportunities. *Teaching Children Mathematics*, *14*(2), 112–116.

Hiebert, J., Morris, A. K., Berk, D., & Jansen, A. (2007). Preparing teachers to learn from teaching. *Journal of Teacher Education, 58*(1), 47–61.

Kazemi, E., & Stipek, D. (2001). Promoting conceptual thinking in four upper-elementary mathematics classrooms. *The Elementary School Journal, 102*(1), 59–80.

McClain, K. (2009). When is an argument just an argument? The refinement of mathematical argumentation. In D. A. Stylianou, M. L. Blanton, & E. J. Knuth (Eds.), *Teaching and learning proof across the grades: A K–16 perspective* (pp. 222–234). New York, NY: Routledge.

McNeal, B., & Simon, M. A. (2000). Mathematics culture clash: Negotiating new classroom norms with prospective teachers. *Journal of Mathematical Behavior, 18*(4), 475–509.

Mottier Lopez, L., & Allah, L. (2007). Sociomathematical norms and the regulation of problem solving in classroom microcultures. *International Journal of Educational Research, 46*, 252–265.

National Council of Teachers of Mathematics (NCTM). (2000). *Principles and standards for school mathematics.* Reston, VA: Author.

Seago, N., & Goldsmith, L. (2005, April). *Turning to the evidence: Examining the impact of two professional development programs focused on algebraic thinking*. Paper presented at the annual meeting of the American Educational Research Association, Montreal, Canada.

Seago, N., Mumme, J., & Branca, N. (2004). *Learning and teaching linear functions: Video cases for mathematics professional development, 6–10*. Portsmouth, NH: Heinemann.

Sherin, M. G., & van Es, E. A. (2009). Effects of video club participation on teachers' professional vision. *Journal of Teacher Education, 60*(1), 20–37.

Smith, M. S., & Stein, M. K. (2011). *5 practices for orchestrating productive mathematical discussions*. Reston, VA: National Council of Teachers of Mathematics.

Stockero, S. L. (2008a). Differences in preservice mathematics teachers' reflective abilities attributable to use of a video case curriculum. *Journal of Technology and Teacher Education*, *16*(4), 433–458.

Stockero, S. L. (2008b). Using a video-based curriculum to develop a reflective stance in preservice mathematics teachers. *Journal of Mathematics Teacher Education*, *11*, 373–394.

Stockero, S. L., & Van Zoest, L. R. (2011). Making student thinking public. *Mathematics Teacher, 104,* 704–709.

Stylianou, D. A., & Blanton, M. L. (2002, July). *Sociocultural factors in undergraduate mathematics: The role of explanation and justification*. Paper presented at the Second International Conference on the Teaching of Mathematics, Crete, Greece.

Van Zoest, L. R., & Stockero, S. L. (2008a). Using a video-case curriculum to develop preservice teachers' knowledge and skills. In M. S. Smith & S. Friel (Eds.), *AMTE Monograph 4: Cases in mathematics teacher education: Tools for developing knowledge needed for teaching* (pp. 117–132). San Diego, CA: Association of Mathematics Teacher Educators.

Van Zoest, L. R., & Stockero, S. L. (2008b). Concentric task sequences: A model for advancing instruction based on student thinking. In F. Arbaugh & P. M. Taylor (Eds.), *AMTE Monograph 5: Inquiry into mathematics teacher education* (pp. 47–58). San Diego, CA: Association of Mathematics Teacher Educators.

Van Zoest, L. R., & Stockero, S. L. (2009). Deliberate preparation of prospective teachers for early field experiences. In D. S. Mewborn & H. S. Lee (Eds.), *AMTE Monograph 6: Scholarly practices and inquiry in the preparation of mathematics teachers* (pp. 153–169). San Diego, CA: Association of Mathematics Teacher Educators.

Van Zoest, L. R., Stockero, S. L., & Edson, A. J. (2010). Multiple uses of research in a mathematics methods course. In J. W. Lott & J. Luebeck (Eds.), *AMTE Monograph 7: Mathematics teaching: Putting research into practice at all levels* (pp. 157–171). San Diego, CA: Association of Mathematics Teacher Educators.

Van Zoest, L. R., Stockero, S. L., & Taylor, C. E. (2011). The durability of professional and sociomathematical norms intentionally fostered in an early pedagogy course. *Journal of Mathematics Teacher Education*. doi:10.1007/s10857-011-9183-y

Voigt, J. (1998). The culture of the mathematics classroom: Negotiating the mathematical meaning of empirical phenonema. In F. Seeger, J. Voigt, & U. Waschescio (Eds.), *The culture of the mathematics classroom* (pp. 191–220). New York, NY: Cambridge University Press.

Yackel, E. (2002). What we can learn from analyzing the teacher's role in collective argumentation. *Journal of Mathematical Behavior, 21*, 423–440.

Yackel, E., & Cobb, P. (1996). Sociomathematical norms, argumentation, and autonomy in mathematics. *Journal for Research in Mathematics Education, 27*(4), 458–477.

Author Note

The research drawn on for this article was supported in part by the National Science Foundation under grant no. ESI-0243558, awarded to Judy Mumme and Nanette Seago, WestEd. The opinions expressed do not necessarily reflect the views of the Foundation.

Authors

Laura R. Van Zoest, Western Michigan University, Department of Mathematics 5248, 1903 W. Michigan Avenue, Kalamazoo, MI 49008; laura.vanzoest@wmich.edu

Shari L. Stockero, Michigan Technological University, 1400 Townsend Drive, Houghton, MI 49931; stockero@mtu.edu