# Chapter 9
# Designing Interactive Technology to Scaffold Generative Pedagogical Practice


**Anthony Matranga, Jason Silverman, Valerie Klein and Wesley Shumar**

**Abstract** This chapter introduces a web-based assessment environment, the EnCoMPASS Environment, that was purposefully designed to scaffold activities consistent with a group of mathematics teacher educators' practices as well as research-based instructional practices. The chapter details the design of the tool and then presents preliminary findings from our analysis of 21 practicing teachers' collective mathematical activity mediated by the tool. Findings indicate that the software environment supported teachers' participation in common practices for examining student work as well as more generative practices such as providing evidence-based feedback. The study has implications for a way in which to conceive of the design of technologies to support generative professional development at a distance.

**Keywords** Technologically mediated professional develop · Software design Teacher professional development

A. Matranga (✉)
California State University San Marcos, San Marcos, USA
e-mail: amatranga@csusm.edu

J. Silverman · V. Klein · W. Shumar
School of Education, Drexel University, 3401 Market Street, Room 358, Philadelphia, PA 19104, USA
e-mail: silverman@drexel.edu

V. Klein
e-mail: vek25@drexel.edu

W. Shumar
e-mail: shumarw@drexel.edu



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## 9.1 Introduction

There is a collective effort amongst mathematics education researchers to develop and refine ways in which to support mathematics teachers' instructional change. It is widely accepted that professional development (PD) is an effective approach to impacting teachers' instruction. There are a variety of approaches to PD that have shown potential to support teachers' instructional change such as PD where teachers plan, rehearse and analyze classroom instruction with teacher educators (Lampert et al., 2013), examine records of practice (i.e. videos of classroom interactions (Sherin, 2007) or student mathematical thinking Jacobs, Lamb, & Philipp, 2010), or participate in communities with generative and productive norms (McLaughlin & Talbert, 2001). There is evidence that community-based PD, in particular, is effective in supporting teachers prolonged and generative change (Vescio, Ross, & Adams, 2008). With advances in technology, research is beginning to investigate the potential for teacher professional development in online spaces (Goos & Bennison, 2008; Matranga, 2017; Trust, Krutka, & Carpenter, 2016). Online communities enhance access to high quality professional development and allow teachers to fit community into their daily schedule. Research also indicates that norms that emerge in alternative contexts are transferable into teachers' instructional practice, even if they come in conflict with instructional norms in teachers' local schools and districts (Vescio et al., 2008).

There is little research that focuses on how to support the emergence of online communities and in particular how to support the emergence of communities that engage particular norms and instructional practices. Our current work aims to address this gap in the literature through the design of an enhanced web-based assessment environment that can scaffold teachers' participation in particular activities that are consistent with a community of teacher educators' practices. The broad goal of facilitating teachers' work with the web-based assessment environment is to support the emergence of generative and productive norms that could transfer into teachers' instructional practice and engender a more student-centered learning environment. This chapter introduces the design of this web-based tool and discusses emerging results from a case study in which we analyzed teachers' use of the tool in the context of an online community-based PD course for practicing teachers.

This chapter is organized as follows. First, we discuss our conceptualization of professional development in order to motivate the design of the tool. Second, we discuss the Math Forum—an online community for mathematics and mathematics education—and their core practices. Third, the web-based tool is introduced in which the design features are intended to scaffold activities consistent with the Math Forum's practices. Fourth, we discuss emerging results from our analysis of teachers' use of the tool. The chapter concludes with a discussion regarding the implications this work has for the design of PD and enhancing mathematics teachers' instruction.

## 9.2 Designing the EnCoMPASS Environment

Our work is grounded in sociocultural theories of learning and in particular communities of practice framework that takes evidence of learning as increasing one's participation in a community of practice (Wenger, 1998). Wenger (1998) argues that social life involves participation in multiple communities of practice, where involvement in a community includes engaging shared practices, having common goals and a shared set of tools. One consequence of this perspective of learning is that as individuals engage in practice with members of a particular community, boundaries often form between those who have been participating in the community and those who have not been participating in the community. Because of this phenomenon, one way to conceptualize engineering learning experiences is through bridging communities, where members of different communities come together and engage in collective practice, thereby engaging a boundary encounter.

Sztajn, Wilson, Edgington, and Myers (2014) conceptualize mathematics teacher professional development as boundary encounters between communities of teachers and communities of teacher educators. Teachers and teacher educators can be conceived of as participating in different communities of practice, as they engage different practices around analyzing and making sense of student thinking. In this sense, Sztajn et al. (2014) argues professional development should be practice-based, where members of these communities are engaging practice around artifacts of teaching.

The concept of boundary objects is used to conceive of artifacts that have potential to support generative work at the boundary between communities. Boundary objects are objects or environments originally conceptualized as effective in mediating activity in the absence of consensus (Star & Griesemer, 1989). One of the properties of boundary objects is interpretive flexibility, that is the potential of an object's perceived use to vary according to the communities in which are engaging with the object (Star, 2010). An artifact with interpretive flexibility has the potential to engender a generative learning environment because when different communities come together and engage practice around the object it is likely that differences in perspective will arise affording opportunities for negotiation and the transformation of practice. Thus, PD activities that include interactions between teachers and teacher educators mediated by a boundary object have the potential to provoke generative conversations.

Our work intended to design a web-based software environment that can function as a boundary object and mediate generative work between communities of teachers and communities of teacher educators. Building on extant research around boundary objects, we conceptualized the design of a tool that could have the same generativity as a boundary object, while situated within a context in which only members of a teacher community are interacting with one another. In this sense, we intended to emulate a boundary encounter between a community of teachers and a community of teacher educators by mediating a group of teachers' work with a software environment that would function as a boundary object but

also scaffold participation in activities consistent with the Math Forum's practices. Thus, documenting the Math Forum's core practices was an important part of the design of the web-based tool. The following section introduces the Math Forum and provides an overview of two of the Math Forum's core practices.

### *9.2.1 The Math Forum*

The Math Forum is a website for mathematics and mathematics education as well as a community of mathematics teacher educators. The Math Forum's website houses services and digital archives designed to mediate communication on the Internet about mathematics as well as to provide resources for teachers when planning instruction. The Math Forum staff are a group of teacher educators who travel the US and conduct workshops with mathematics teachers and promote student-centered instruction consistent with instructional practices called for by the NCTM (e.g. orchestrating rich mathematical discussions, scaffolding peer-to-peer argumentation, etc.) (NCTM, 2000).

In our work with the Math Forum over the last two decades we have documented what we refer to as the Math Forum's core practices. One of these core practices we refer to as *valuing*. Valuing is grounded in the belief that "individuals have great things to contribute" (Renninger & Shumar, 2004, p. 197) both mathematically and otherwise. Valuing is operationalized in the Math Forum's activity of noticing and wondering. Noticing and wondering at the Math Forum originated in staff's PD work with teachers as a way to frame the ways in which they looked at student work (Shumar & Klein, 2016). Noticing frames interrogation of students' ideas as a way to attend to the mathematical details of students' thinking and then wondering is a process of grounding analysis in students' thinking by asking specific questions. This activity is at the core of the way in which the Math Forum works to understand students' mathematical thinking.

The second core practice of the Math Forum is providing *evidence-based feedback*. This practice of the Math Forum can be likened to a "research lens," or a process of developing and testing conjectures to better improve conditions for learning. Providing evidence-based feedback includes two activities: (1) collecting evidence of student thinking through processes of noticing and wondering, and then (2) reflecting upon this initial layer of analysis to parse through noticings and wonderings as a means to target aspects of student thinking that are likely inchoate forms of significant mathematical understandings. The Math Forum staff use these activities to prepare to design feedback that can create an environment for students to expand their mathematical understandings. Following providing feedback to students, the Math Forum staff reengage these activities to further understand student mathematical thinking and support learning.

In regard to the broader landscape of mathematics education research, the Math Forum's core practices are consistent with the NCTM's principles and standards for mathematics as well as research-based instructional practices that advocate

student-centered instructional strategies. *Valuing* and providing *evidence-based feedback* are consistent with calls by the NCTM to provide **all** students opportunities to engage rigorous mathematical thought (NCTM, 2000). Valuing students' ideas by focusing on the details of their thinking and grounding analysis within this thinking is a way to take *each and every* student's thinking seriously. Moreover, providing evidence-based feedback is a way to support *each* student in expanding his or her current way of knowing through linking feedback to that student's mathematical thinking. In addition, valuing and providing evidence-based feedback are consistent with practices such as professional noticing (Jacobs et al., 2010) and formative assessment (Heritage, Kim, Vendlinski, & Herman, 2009). The professional noticing framework involves attending to the details of student thinking and interpreting the meaning of these details for students' mathematical understandings while developing this understanding of student thinking is a starting point for designing feedback and learning environments that support student mathematics learning.

Taken together, the Math Forum's practices are at the core of their success as a community of mathematics teacher educators and their practices are consistent with those called for by research and policy to improve mathematics education in the United States. Thus, our work began with the conjecture that designing a web-based assessment environment that could scaffold activities consistent with the Math Forum's practices has the potential to improve teachers' mathematics instruction to become more consistent with what is called for by research and policy.

## *9.2.2 The EnCoMPASS Environment*

The EnCoMPASS Environment is designed to function as a boundary object through affording participation in teachers' existing practices for organizing and assessing student work and it is also designed to scaffold activities for examining student work consistent with the Math Forum's practice of valuing and providing evidence-based feedback. Thus, the following introduces (1) the landscape of the EnCoMPASS Environment and its design features, (2) the way in which these features scaffold activities consistent with the Math Forum's practices, and (3) the way in which the tool is designed to function as a boundary object by affording participation in teachers' existing ways of examining student work.

### 9.2.2.1 The Landscape of the EnCoMPASS Environment

The EnCoMPASS Environment is a web-based assessment environment that provides a space for teachers to upload sets of student work into a primary workspace (shown in Fig. 9.1). The design features of the EnCoMPASS Environment are intended to enhance the process of looking at student work and developing feedback. The primary workspace is separated into three panels. Student work is

populated into the middle panel while the left and right panels scaffold the analysis of students' work. The features that support this analysis include a selection tool, a noticing and wondering commenting tool (center pane), the capacity to sort and categorize (left pane) and aggregate for future use and feedback (right pane).

The *selection tool* is designed to scaffold a process of highlighting aspects of students' work. Selections are collected at the bottom of the screen below the student's work (shown in yellow in Fig. 9.1). In the right panel, there is a text field that provides space for teachers to record their thinking. These comments are in the form of "*I notice…*" and "*I wonder…*" and are directly linked to selected aspects of the student's work. Below the text field is a list of the noticings and wonderings, which are available for reuse. In the left panel, there is a *categorization system* or folders, which facilitate organization of selections and comments. This feature allows teachers to develop a set of folders and sort selections based on different characteristics (i.e. strategy used to solve the problem, completeness, correctness, etc.). Lastly, the EnCoMPASS Environment has an *aggregation system* that organizes teachers' selections, noticings and wonderings for a specific students' work and organizes them into the *feedback screen* (shown in Fig. 9.2). For example, in Fig. 9.2, following "you wrote:" is an aspect of student work that the teacher highlighted using the selection tool. Moreover, following "…and I noticed that…" is the comment the teacher made using the noticing and wondering commenting field on that particular selection. In this screen, teachers can also edit their selections/noticings/wonderings to develop a coherent note that is sent to a student.

While this section introduced the functionality of the EnCoMPASS Environment's features, the following relates the activities in which these features scaffold to the Math Forum's practices.

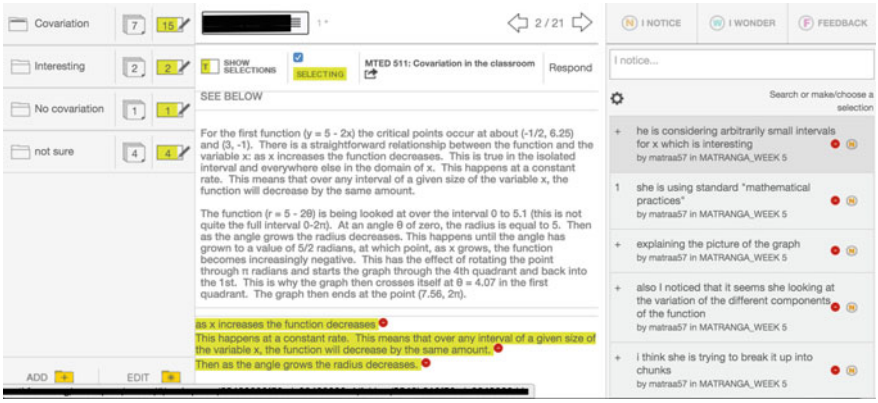


**Fig. 9.1** Primary workspace in the EnCoMPASS environment (color figure online)

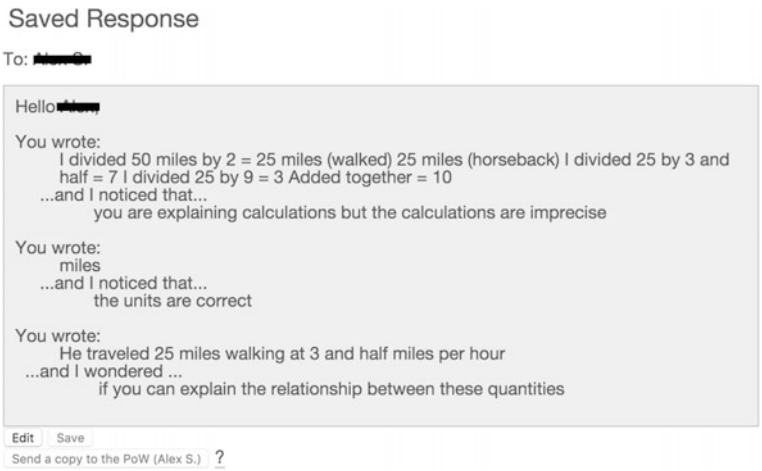


**Fig. 9.2** The feedback screen

#### 9.2.2.2 Scaffolding Activities Consistent with the Math Forum's Practices

Table 9.1 provides an overview of the conjectures that guided the design of the EnCoMPASS Environment and this section details how the features of the environment scaffold activities consistent with the Math Forum's practices of valuing and providing evidence-based feedback. The Math Forum's practice of *valuing* takes seriously the notion that everyone has something to contribute to a conversation and is operationalized through the activity of noticing and wondering. Noticing and wondering includes activities such as focusing on the details of student thinking and grounding analysis in these details by asking specific questions. The *noticing and wondering commenting field* and *selection tool* are designed to scaffold the activities just mentioned.

The noticing and wondering commenting tool provides an entry point into focusing on the details of student work and grounding analysis in these details. Noticing frames analysis of student work through the lens of "I notice," which is intended to focus user's attention on anything that is interesting, unique or questionable. Once an aspect of student work is "noticed," framing additional thinking through "I wonder" is intended to scaffold careful thinking about what the "notice" or evidence of student thinking could say about the students' mathematical understandings. In this sense, the activity of noticing and wondering sets a frame around which the user engages with the selection tool.

The primary activity in which the selection tool supports as well as its underlying functionality further scaffold activities of focusing on the details of student thinking and grounding analysis within this thinking. In particular, the selection tool scaffolds these activities by supporting the process of "selecting" or "highlighting" aspects of students' work noticed by the analyst. As aspects of student thinking are

**Table 9.1** Conjectured relationship between features, activity and practice

| Design features | Activity | Math Forum practice |
|---|---|---|
| • Selection tool<br>• Noticing and wondering commenting field | • Focusing on the details of student thinking<br>• Grounding analysis in student thinking | Valuing |
| • Aggregation system | • Reflect upon evidence of student thinking to develop focused feedback | Evidence-based feedback |

selected, they are aggregated at the bottom of the screen (see Fig. 9.1—shown in yellow at the bottom of the center panel in the primary workspace). This isolates instances of student thinking and affords the opportunity for additional thinking to be done by the analyst about these details as well for the analyst's thoughts to be recorded with the noticing and wondering commenting field. In addition, the EnCoMPASS Environment generates a link between the selection and comment, thus scaffolding the grounding of analysis in student thinking. In particular, in order to record a notice or wonder in the text field one of the highlighted aspects of student work collected at the bottom of the screen must be 'clicked' prior to recording the comment in the noticing and wondering commenting field. Moreover, once a comment is made, if the user clicks on a comment from the list of comments in the right panel of the primary workspace the corresponding selection highlighted in yellow at the bottom of the center panel in which this comment was connected is underlined in red. To this end, the EnCoMPASS Environment is designed to mediate activities involved in noticing and wondering and, consequently, *valuing* by focusing user's analysis on details of student thinking as well as by grounding this analysis in student thinking. While these aspects of the tool's design are intended to support the analysis of student work, the aggregation system is intended to support the design of feedback in ways that are consistent with the Math Forum's practice of providing evidence-based feedback.

In fact, the Math Forum's practice of providing *evidence-based feedback* is regarded as a 'research lens' for examining student thinking, which includes two

activities (1) collecting evidence of student thinking through process of noticing and wondering, and (2) reflecting upon this initial layer of analysis to develop focused feedback.

The selection tool and noticing and wondering commenting field of the EnCoMPASS Environment are designed to scaffold activity consistent with the initial process of providing evidence-based feedback. Thus, the initial layer of analysis of student work results in a collection of highlighted aspects of student thinking and noticings/wonderings that are explicitly linked to this data. The EnCoMPASS Environment therefore creates residue of this first pass of analysis of student thinking and then when the user is ready to develop feedback, the *aggregation system* transitions users to the *feedback screen* (shown in Fig. 9.2), which aggregates selections/noticings/wonderings in order to provide a snapshot of the thinking done in the initial analysis. This screen scaffolds reflection on the initial layer of analysis as there is an "edit button" that allows users to adjust, reword, reorganize and build upon the thinking done during the initial analysis. In this way, the feedback is grounded in student thinking as users are supported in transforming evidence of student thinking and documentation of their own thinking that is linked to this evidence into a focused feedback note designed to support students in expanding their mathematical ways of knowing.

#### 9.2.2.3 Teachers' Existing Practice

In addition to scaffolding activity consistent with the Math Forum's practices, the EnCoMPASS Environment was also designed to afford participation in teachers' common practices for preparing for and providing students feedback on their mathematics work. With decades of experience working with teachers, we have found that when presented with a pile of student work teachers (1) sort the work into different piles, (2) assess students' mathematics work, and (3) provide feedback to students based on previous experiences. Sorting student work includes placing students' papers into piles according to particular commonalities in their work. For example, pile A might be 'correct,' pile B might be 'incorrect' and so on. The categorization system of the EnCoMPASS Environment affords participation in this practice as teachers can quickly scan through student work and then place it into folders that are named according to the particular commonality in their work. We also have found that teachers tend to assess student work by circling aspects of a student's work and making brief comments about the particular mistake. The selection tool and noticing and wondering commenting field affords participation in these activities as teachers could highlight, for instance, a calculation error and then comment about what went wrong or how to fix the error. The tool also affords the development of feedback according to teachers' experiences as they could look at student work and then transition directly to the feedback screen without using the selection tool or the noticing and wondering commenting field.

The way in which the EnCoMPASS Environment affords participation in practices for preparing for and providing students feedback on their mathematics

work is consistent with what we have found is typical for practicing teachers and is important for the tool to function as a boundary object. If the tool was not designed to have interpretive flexibility and support participation in such activities, it is unlikely that teachers would perceive the tool as useful and might not legitimately engage with the EnCoMPASS Environment.

## 9.3 Examining Teachers' Interactions Mediated by the EnCoMPASS Environment

In one of our initial use cases of the EnCoMPASS Environment, we integrated the tool into an online community-based PD course for practicing teachers that included exclusively asynchronous communication. The existing structure for engaging collaborative problem solving in the course included providing teachers with a problem in which they would spend 3–4 days to work privately on drafting a response and then post their response to the course. Teachers would then review their colleagues' work and provide them feedback. The final stage included revising the initial submission according to their colleagues' feedback. Modifying this process for this study, participants uploaded their colleagues' work into the EnCoMPASS Environment and then used the web-based tool to scaffold the process of providing their colleagues feedback.

The current study included 21 practicing teachers who participated in the online PD course. The participants were primarily novice teachers that ranged from only having student teaching experiences to three years of experience in the classroom. The analysis in this study used a grounded theory methodology (Glaser & Strauss, 1999) where we conducted open and axial coding procedures with participants' mathematics work and the EnCoMPASS-scaffolded feedback they developed.

### *9.3.1 Findings*

Participants used the EnCoMPASS Environment to examine their colleagues' work and provide feedback for seven of the ten weeks of the course. The tool was introduced in week three and then participants used the tool for each of the following weeks except week seven and ten. Week seven and ten did not include problem-solving activities in which participants used the EnCoMPASS Environment to provide one another feedback because in week seven a group assignment replaced the typical mathematical activities and week ten was reserved for reflective activities. During each of the weeks in which participants used the EnCoMPASS Environment, they examined two of their colleagues' work via the tool and then sent the result of this analysis to their colleague as feedback. As we examined the ways in which participants engaged this process scaffolded by the tool

we began to recognize several patterns. We identified a pattern in the connection between the aspects of the mathematics work in which participants were highlighting and the comments they made about these highlights as well as a pattern in the feedback participants were crafting using the noticing and wondering commenting tool. The following briefly examines these patterns, however prior to doing so, we first show that participants used to the tool for its designed use.

#### 9.3.1.1 Using the Tool's Features for Their Intended Use

Through the analysis of participants' interactions mediated by the EnCoMPASS Environment's design features, there is evidence that the tool scaffolded participants' activity in the activities in which it was intended to scaffold. Participants used the selection tool to highlight details of their colleagues' mathematics work and then used the noticing and wondering commenting tool to develop comments connected to these details. Following the use of these features, participants sent the result of their analysis to their colleagues as feedback. An example of the feedback participants developed is shown in Fig. 9.3.

The reader will notice in Fig. 9.3 that the feedback is in the form of a list of text labeled "You wrote…," "…and I noticed that…" or "…and I wondered about…" The EnCoMPASS Environment generates these labels. "You wrote:" signifies the particular instance of mathematical thinking a participant highlighted using the selection tool while "…and I noticed/wondered that/about…" signify the comment participants made using the noticing and wondering commenting tool. Given the "look" of participants' feedback (in which a representative example is shown in

```
You wrote: relationship between a length x and the area of a rectangle with sides 2x and
    3x

    ... and I noticed that ... these are the quantities you are focusing on

You wrote: area of a rectangle with sides 2x and 3 is dependent on the value of the
    quantity x.

    ... and I noticed that ... quantities you are working with and the relationship

You wrote: x-intercept and a y-intercept of zero. This is a result of the fact that if the
    length X is zero than the area must be zero.

    ... and I noticed that ... I made the connection of the area being zero when the
        length of x was 0, but I didn't relate that to the x and y intercept. Nice
        connection

You wrote: the vertex is a minimum because the area cannot be negative therefore the
    smallest area possible is zero.

    ... and I noticed that ... good explanation of this value

You wrote: parabola with an axis of symmetry through x=0

    ... and I wondered about ... if you could explain the axis of symmetry. It may help in
        student understanding.

You wrote: As x is squared, this allows for the graph to exist when x is negative even
    though we do not measure negative lengths.

    ... and I noticed that ... This is a great way to explain the negative length. I used
        the idea that we were measuring in the opposite direction so the negative
        represents direction.
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**Fig. 9.3** Example feedback developed scaffolded by the EnCoMPASS environment

Fig. 9.3), it appears that the tool scaffolded participant's development of feedback in the way in which it was designed to because participants selected the details of their colleagues' work and then developed comments connected to these details.

To place this use case in contrast to one that would have come in conflict with the EnCoMPASS Environment's intended use, participants could have used the selection tool to select the entirety of their colleague's initial response and then make broad comments about their colleague's work using the noticing and wondering commenting tool. Moreover, participants could have used the selection tool to highlight details of their colleague's work and then transitioned directly to the feedback screen to provide feedback without using the noticing and wondering commenting tool. Nevertheless, the above example shown in Fig. 9.3 provides evidence that participants used the EnCoMPASS Environment for its designed use.

### *9.3.2 Linking Comments to Data*

Closer analysis of participants' feedback indicates that participants explicitly linked their noticing and wonderings to evidence of their colleagues' thinking and they did so in two ways. First, participants used pronouns such as "this" or "here" to refer to the highlighted portion of their colleague's work in which they were referring to in the comment they developed with the noticing and wondering commenting tool. Moreover, participants linked the content of the highlighted aspect of their colleague's work with the content of their noticing/wondering. For example, consider the following representative example from an occasion where the class is making sense of the quantities from the unit circle (e.g. arc length, vertical/horizontal distances from the circumference of the circle to the axes) in order to make sense of the behavior of the sine function.

> **(Jazmine's selection from Rose's work)** You wrote: domain
>
> **(Jazmine's Comment on the above selection)**…and I noticed that… you used the word domain; I don't think I did
>
> **(Jazmine's selection from Rose's work)** You wrote: x represents the angle or the arc length of the circle
>
> **(Jazmine's Comment on the above selection)**…and I wondered about… I think this is different from my explanation. I wonder if one of us is correct; or if we are both correct, but saying it differently.

In the first selection, Jazmine highlighted Rose's use of the word 'domain' from her solution and then in Jazmine's comment on this selection she noticed that Rose used the word domain. Jazmine's second selection highlighted Rose's description of a particular quantity ("the angle or arc length…") and then in her comment on this selection, Jazmine wondered, "I think *this* [emphasis added] is different…".

This example illustrates the way in which Jazmine linked her comments to the selections she made from Rose's work. First, Jazmine used the design features for their intended use as she selected the details of Rose's work. In Jazmine's first

comment, there was a link between the content of Rose's work and the content of her comment, namely the word "domain." In Jazmine's second comment, she explicitly referenced Rose's work with use of the word "this." Thus, in both cases there was a specific highlighted detail of Rose's work and an explicit link between this detail and the comment. In particular the link was through (1) common use of terms (e.g. domain) and (2) pronoun usage to refer to the selection.

This was the typical way in which participants provided feedback to colleagues scaffolded by the EnCoMPASS Environment, which was consistent with the operationalization of *valuing* through noticing and wondering. As noted above, noticing and wondering includes focusing on the details of student work and then grounding analysis in these details. Thus, there is evidence that the EnCoMPASS Environment scaffolded activities that are consistent with the Math Forum's practice of *valuing*, as participants highlighted the details of colleagues' work and then linked their comments to this evidence of their colleagues' thinking.

#### 9.3.2.1 An Emerging Purpose for Feedback

Emerging from participants' use of the selection tool and noticing and wondering commenting field was a pattern in the feedback they provided to colleagues that had the purpose of challenging colleagues to refine the details of their mathematical explanations. When challenging colleagues, participants linked their feedback to data and explicitly asked colleagues to further refine and expand upon their mathematical explanations. To illustrate this use of the tool, an example is taken from an activity where participants were working with the function $y = \sin(x)$. Consistent with the goals of the course, participants were attempting to examine the relationship between quantities to make sense of the behavior of $y = \sin(x)$. There were a number of cases where participants develop explanations that were not consistent with the goals of the course, which invoked occasions where participants would challenge colleagues who developed such explanations. The following illustrates how Paul used the tool to develop feedback that challenges Nina to refine her mathematical explanation.

> **Paul's selection from Nina's work:** You wrote: This graph appears as it does because of the Unit Circle. Essentially as the values of sin(x) make their way around the circle, they start again at zero.
>
> **Paul's comment to Nina:**…and I wonder… if you could elaborate on this concept more. Why do the values start again at zero? Why does the graph have hills and valleys?

Using the selection tool of the EnCoMPASS Environment, Paul highlighted an aspect of Nina's work and then made a comment grounded in this detail as he used "this" to refer to Nina's work when Paul said, "if you could elaborate on *this* concept more." In his comment, Paul challenged Nina to expand her mathematical explanation when he said, "Why do the values start again at zero?" "Why does the graph have hills and valleys?" Part of the reason why this was regarded as a challenge is because the class was working collectively to explain why graphs look

a particular way and it appears that Nina did not include such a description in her explanation.

While the EnCoMPASS Environment scaffolded participants' examination of the details of colleagues' thinking and grounding comments within those details, there was nothing inherent about the tool's design features that scaffolded challenging colleagues. Therefore, it appears that challenging was emergent, in that the purpose of the feedback emerged through the use of the EnCoMPASS Environment for developing feedback.

Taken together, the brief examination of participants' use of the EnCoMPASS Environment for developing feedback illustrates that (1) participants used the design features for their intended use as they made selections and made comments connected to these selections, (2) the tool scaffolded activities consistent with the Math Forum's practice of *valuing* as participants began to explicitly link their noticings and wonderings to data, and (3) the purpose of participants' feedback was emergent in that the tool was not designed to scaffold challenging colleagues to refine their mathematical explanations.

## 9.4 Discussion

The intention of the design of the EnCoMPASS Environment is to scaffold generative and productive norms for preparing for and providing students feedback on their mathematics work (consistent with the Math Forum's practices) that can transfer into teachers' instructional practice and engender a more student-centered learning environment. This study found that the design features of the EnCoMPASS Environment scaffolded activities in which they were designed to scaffold. Moreover, as a result of this activity, participants began to engage practices for preparing and providing feedback to students in ways in which were consistent with the Math Forum's practice of valuing and developing generative feedback through challenging colleagues. This result suggests the potential of the EnCoMPASS Environment to scaffold generative work between teachers in online community-based PD.

Earlier in this chapter, we mentioned that research indicates that norms that emerge in alternative contexts are transferable into teachers' instruction. While this study did not document the emergence of norms, as a result of participation in this study it is more likely that participants would focus on the details of their students' thinking and then link feedback to this data. Moreover, there was likely an increased potential for participants to challenge students to refine their mathematical explanations. In this sense, students' ideas would become more central to teachers' instruction as teachers use student thinking as the foundation on which they think about how to respond to students and move the class forward in their thinking. Thus, there is potential that participation in community-based PD mediated by the EnCoMPASS Environment can support teachers in moving along a trajectory from teacher-centered to student-centered instruction.

## 9.5 Conclusion

This study found that a technology mediating interactions in a collaborative environment had potential to impact teachers' mathematics instruction rather than a group of teacher educators facilitating PD activities. A digital platform, namely the EnCoMPASS Environment, was designed to emulate teacher or student participation within the Math Forum and appeared to have potential impact on the ways in which teachers provide one another feedback on their mathematics work in similar ways in which participation in PD with the Math Forum staff would impact these practices. This suggests that this environment has the potential to impact the norms and practices of an online community of teachers and ostensibly impact teachers' classroom practice. Given that the tool could be integrated into multiple contexts simultaneously, it has the potential to enhance the scale at which the Math Forum could impact mathematics teachers' instruction.

While there is emerging evidence that this tool began to scaffold participation in generative and productive norms for providing feedback, we are still in the process of analyzing data to make sense of how the tool's design to function as a boundary object impacted teachers' use of the EnCoMPASS Environment. At this phase of the analysis, we have preliminary conjectures that emerged through observations from facilitating teachers' use of the tool in the online PD course. In particular, we observed teachers expressing affect towards the design of the tool and its potential to make analysis of student work more efficient.

In summary, at this stage of our work, there is evidence that the EnCoMPASS Environment is functioning as a boundary object because it is perceived as legitimate and the design features have interpretive flexibility through their use to share and compare information as well as to challenge colleagues. Given our findings from the study presented in this chapter, we argue that conceptualizing the design of technology as a boundary object is one way in which to conceive of a scalable design for collaborative and technologically mediated professional development that takes place at a distance. Future research is needed to better understand how the EnCoMPASS Environment functions as a boundary object and how functioning as such is significant for scaffolding participation in activities consistent with the Math Forum's practices.

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