TEACHERS' ANALYSIS OF STUDENT THINKING IN A TEACHING MATHEMATICS WITH TECHNOLOGY MASSIVE OPEN ONLINE COURSE

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The research study examined the ways participants analyzed students' mathematical thinking in a massive online open course focused on teaching mathematics with technology. Across units, participants' posts showed increased attention to student thinking and less focus on issues related to technology.

Keywords: Technology, Teacher Professional Development

Introduction

Effective professional development is intensive, ongoing and connected to practice. It connects to teachers' professional practice and develops relationships among teachers (Darling-Hammond, Wei, Andree, Richardson, & Orphanos, 2009; Loucks-Horsley, Hewson, Love, & Stiles, 1998). Research provides support for seven key features that are essential for providing effective professional development for teachers (e.g., American Federation of Teachers, 2002; Borasi & Fonzi, 2002; Darling-Hammond, et al., 2009; Garet, Porter, Desimone, Birman & Yoon, 2001; Sparks & Hirsh, 1997). These features include assurance that professional development: broaden and deepen teachers' understandings of the content they are teaching; strengthen teachers' pedagogical skills specific to teaching a particular discipline; provide opportunities for teachers to understand how students learn and appreciate differences in student thinking; be connected to the practice of teaching (lesson planning, assessing student thinking, curriculum development, implementation of activities); be ongoing, job-embedded and site specific and continuously interwoven in the daily work of teachers; engage teachers in ongoing discussions within professional communities focused on content, teaching, and learning; provide supports for change that include personnel, materials, equipment, and time.

With technology rapidly changing, teachers often seek out professional development opportunities to learn about new tools. However, research shows that just adding technology to the classroom is not sufficient (e.g., Ertmer, 1999). Teachers need to understand how technology can be used to support students' mathematical thinking. This requires teachers to attend carefully to students' work and thinking.

Building on the work of van Es and Sherin (Sherin & van Es, 2005; van Es & Sherin, 2002; van Es & Sherin, 2010) who examined teachers' noticing of student thinking from video recordings of classrooms, Wilson, Lee, and Hollebrands (2011) developed a model for characterizing prospective teachers' attention to students' work and actions and interpretations of students' mathematical thinking while analyzing a video of students' work with technology. The model facilitated the identification of four distinct processes teachers use to make sense of student work and thinking: describing, comparing, inferring, and restructuring. **Describing** is characterized by an explicit focus on the actions and words of students. Teachers may repeat the same words that were spoken by the students or provide a detailed account of the menus that were selected while using the technology. **Comparing** is characterized by teachers considering their own work on the task with students' actions, either implicitly or explicitly. **Inferring** involves teachers in making assumptions about students' mathematical knowledge to make

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inferences about what students are thinking. The final category, **restructuring**, occurs when teachers' own knowledge about mathematics, teaching, or technology is modified based on their analysis of students' work and thinking.

The purpose of this study was to examine what teachers focused upon when attending to student work and thinking while participating in online discussion forums within a teaching mathematics with technology professional development course. When teachers focused on student thinking, we were interested in examining the processes teachers used to make sense of students' work with technology.

Context

With a focus on strengthening teachers' pedagogical skills, knowledge of technology, and appreciating differences in student thinking, the first two authors and members of the design team created a Massive Open Online Course, "Teaching Mathematics with Technology." The goals of the course are for teachers to become more familiar with different types of technology and pedagogical strategies that can be used to support mathematics teaching and learning. In addition, we desire for teachers to become aware of the ways students reason and think by providing opportunities for them to analyze videos of students' working on mathematical tasks with technology. A summary of the course and opportunities included for teachers to analyze students' thinking is included in Table 1.

Table 1: Description of Units and Opportunities for Teachers to Analyze Student Thinking

Unit Title	Opportunities to Analyze Student Thinking
Unit 1: Affordances of Technology for the Teaching and Learning of Mathematics	Two video recordings of pairs of students completing the Penny Circle task are provided. In one video students use Demos, in the other video students use paper and pencil to complete the task.
Unit 2: Capitalizing on the Power of Technology	A video recording of a pair of students completing the "Three Animals" task using Geogebra is provided.
Unit 3: Interacting with Engaging Mathematical Tasks	A video of two students completing a "Mystery Transformations" task using WebSketchpad is provided. Three videos of students solving a geometry, statistics, and algebra task are also provided. Teachers can select one to view and analyze.
Unit 4: Using Multiple-Linked Representations	An animation of a classroom scenario involving a discussion of a statistics task using CODAP is provided.
Unit 5: Assessing Students' Mathematics Thinking	A video of a class using Plickers to conduct formative assessment is provided.

The course was first offered in Fall 2016. The first unit opened October 3rd. Subsequent units were opened weekly and the entire course remained open until mid-December. Each unit contained two discussion forums where participants were encouraged to respond to prompts and to each other. One discussion forum was included in the "Essential Exploration" section where a technology-based mathematical task was presented for teachers to solve. It was followed by a video or animation of students' work on that same task. The second discussion forum was included in the "Connect to Practice" section where additional tasks and/or videos of students or classrooms were provided. Although each unit was opened weekly, participants could work at their own pace and choose to complete activities that were of interest to them. Participants interested in obtaining a certificate of completion were required to access the Essentials (readings and videos), complete the Essential Exploration, and post at least one discussion or comment in each of the two discussion forums within each unit.

Participants and Methods

A total of 534 individuals registered for the course, while 337 accessed the course and 236 posted to the discussion forums. At the conclusion of the course, all discussion forum posts were downloaded into a .csv file. Data were cleaned to remove html codes and personal identifiers. Because we were interested in how participants analyzed student thinking, we focused on discussion forum posts from units 1, 2, and 3 that included opportunities for participants to analyze student thinking. This included five discussion forums (two from Unit 1, one from Unit 2, and two from Unit 3) resulting in 271 discussion threads. From these 271 discussion threads, a decision was made to focus on 35 participants who posted in two or more of the five forums.

These 35 participants resided in four countries, with the majority in the US (89%). Within the US, most of the participants resided in the South (48%), while 23% lived in the Midwest, 19% resided in the Northeast, and 10% resided in the West. The majority were female (89%). The highest degree completed by 23% of the participants was a 4-year college degree, while most held advanced degree (69% and 9% had obtained a master's degree and PhD, respectively). The majority of participants were classroom teachers (82%); other participants included administrators (6%), undergraduate and graduate students (3%), university faculty (3%), and other (6%). Participants background with respect to number of years of experience was diverse, with a mean of 14.59 years and a median of 11.5 years. Most of the participants specialized in high school (46%) and middle grades (37%), while others specialized in post-secondary or a combination of the specialization already mentioned.

The data were organized by each of the 35 participants to examine their posts across units. A total of 174 posts made by the 35 participants were analyzed across three units. Of those 174 posts, 79 came from Unit 1, 27 from Unit 2, and 68 from Unit 3. With a total of 174 posts and 35 participants, the average number of posts per participant across all units was 4.97.

Each post was then coded to indicate whether the post was about student thinking or not (yes or no), what the post was focused on (technology, task, students, mathematics, teaching) and if the post was about student thinking the way they were analyzing student thinking (describing, comparing, inferring, restructuring, other).

The **describing** category was used if the post provided details about what the students did or said. For example, one participant posted, "The technology using pair of students used interactive coordinate plane, click and drag (mouse) digital data tables." **Inferring** was defined as a post that includes an assumption about student thinking or motivation. For example, one participant posted "The technology option allowed them to see the patterns much easier and with more possibilities." **Comparing** was defined as a post that included a direct relationship between the work of the participant and the work of the student. For example, one participant posted, "When I was doing the task, I was trying to ask myself the same questions the boys asked in the video." **Restructuring** was defined as a post that included evidence that the participant learned something about mathematics, teaching, or student thinking from their analysis of student thinking. For example, one participant wrote, "What I noticed with the video of the students who used paper and pencil, they actually collected data for various circles. They used this data to create a graph. By looking at the data, they determined that a quadratic equation was a best fit for the data. I think that the students should do this activity first and then go to Desmos to determine the equation that would be a best fit of the data." We also had a code, **Other**, that was used to code posts that did not fit the four existing categories. Within the Other category there were two themes: **contrasting paper/pencil to technology** and **anticipating or comparing to own students or students in general**. This post was coded as contrasting paper/pencil to technology, "The paper-pencil method definitely took a lot longer and there was not enough data to be seen." The following post was coded comparing to students, "I have a similar issue with my students and it is tough to not give them too much, but enough to get them exploring to a point they have enough to make good conjectures on."

The researchers coded an initial subset of posts collaboratively. Once there was consistency in coding, each post was coded by three researchers, these codes were discussed until a consensus was reached. If there was disagreement about a particular code, definitions were refined to provide greater clarity.

The Focus of Teachers' Attention

For those posts that were focused on student thinking 66% were about students or task, which is not surprising. For those posts that did not address student thinking, the focus was somewhat equally distributed among technology, teaching, task, and students (See Figure 1).

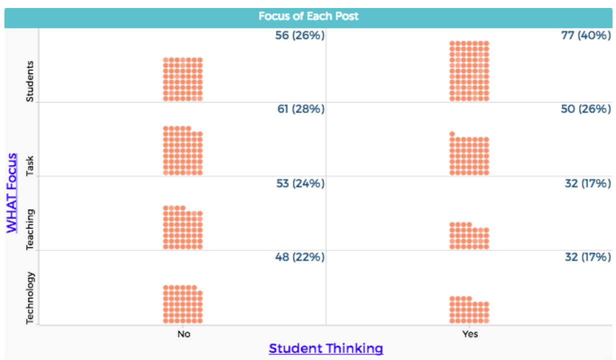

Figure 1. The focus of each discussion forum post and its consideration of student thinking.

It appears that when participants did not address student thinking, they still attend to task but focus more attention on issues related to teaching and technology. Themes within the posts that did not address student thinking were: participants own solution of the task with technology, contrasting paper/pencil and technological approaches, general discussion about students' mathematical work, teaching concerns.

Several posts referred to teachers' own work with technology. For example, one participant noted, "I also had difficulties with software, but it means I need to practice more." Another participant stated, "I started with the linear model too! The exponential model got crazy large. I like that when I picked that one, the simulation questioned that one and prompted me to go back." Participants also discussed how different tools (paper/pencil, technology) can be used to support students' learning. For example, one participant exclaimed, "Yes! I agree that students need a combination of both methods as technology should enhance the experience and not do it completely for them!" and another participant commented, "The technology allows learners to use more functions and visualise the circle with unlimited pennies and may notice the large difference when the functions and graph are done by hand writing." Several posts addressed general teaching concerns such as, "I teach developmental math at college level. I think technology is good for teaching and learning. But I have classes in a room without computers. So

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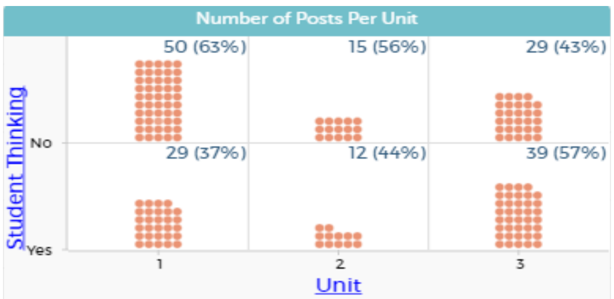
I mostly think about using technology and demonstration on the screen for the whole class to see." While others referred to students in a general way, "Students sometimes have a hard time figuring out if their predictions are good or bad. With this program, they are able to immediately determine if the estimates were good or bad."

Because opportunities to analyze students' thinking were included in each unit, teachers' attention to student thinking across the units was examined. As shown in Figure 2a, there was increased attention to student thinking across units (from 37% to 44% to 57%). While the majority of the posts were identified as "not student thinking" in Units 1 and 2 (63% and 56%, respectively), the majority of the posts were identified as "student thinking" in Unit 3 (57%). In addition to analyzing whether a post was about student thinking or not, researchers examined the focus of each post across units. In Figure 2b, it is evident that of all the posts that were coded as focusing on technology, the majority occurred in Unit 1 (61%) and decreased in Units 2 and 3.



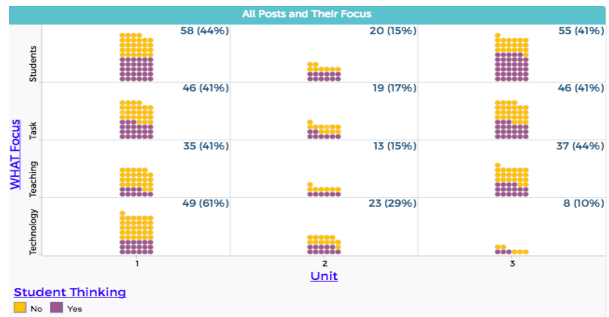
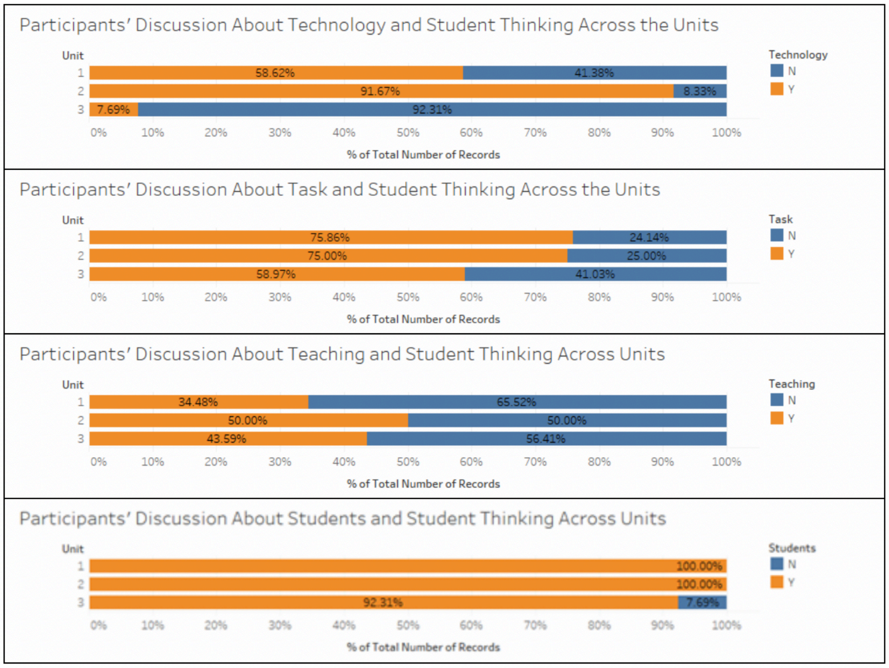


Figure 2a. Number of discussion forum posts focused on student thinking across units.

Figure 2b. Proportion of coded discussion forum posts in each of the units.

Focusing only on those posts that were coded as addressing student thinking, we see that the number of posts that also address technology increased from Unit 1 to Unit 2 and then decreased in Unit 3 (Figure 3a). Although not as drastic, there was a similar result for the discussion of tasks, where 59% of the discussion in Unit 3 of the posts identified as student thinking were also discussing the task, whereas those percentages were slightly higher in Units 1 and 2 (76% and 75%, respectively- Figure 3b). In addition to discussing the technology and the task related to student thinking, participants also discussed students and teaching. Posts about teaching and student thinking increased from Unit 1 to Unit 2 (See Figure 3c) and posts about students and student thinking stayed fairly consistent across units (Figure 3d).

One of the purposes of this research study was to examine what teachers focused upon when attending to student work and thinking while participating in online discussion forums within a teaching mathematics with technology professional development course. We found an increase in the number of posts that analyzed student thinking across units. When posts were not focused on student thinking, they tended to address teaching or technology. Within posts that addressed student thinking we saw different trends in the ways teachers discussed technology, teaching, task, and students.



Figures 3a-3d. Focus of posts coded student thinking.

The other purpose of this study was to examine processes teachers used when examining student thinking. If a post was coded as addressing student thinking, it was coded for the process that was used (describing, comparing, inferring, restructuring, and other) to make sense of student thinking. Findings to this question are presented in the following section.

How Teachers Analyze Students' Work and Thinking

Posts that included an analysis of student thinking were coded in terms of describing, comparing, inferring, restructuring or other. Many of the teachers analyzed student thinking and responded by: 1) describing and inferring, 2) inferring and restructuring, or 3) describing, inferring, and restructuring. However, others indicated that they had solved the task themselves using technology, anticipated student strategies, made comparisons to their own thinking, and/or described/made inferences about student thinking (See Figure 4). We found that some teachers made two other types of comparisons: comparisons to their own students or students in general.

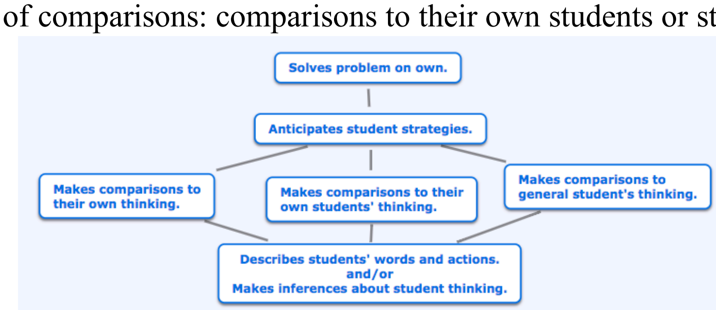


Figure 4. Teachers' patterns of analysis of student thinking.

Across all units, posts typically included inferences about students. They also included descriptions of students' actions or words. Less often, we saw instances of restructuring (Figure 5).

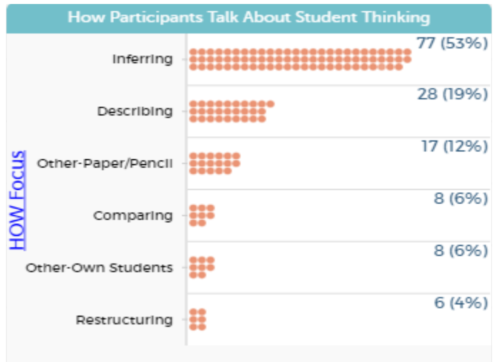


Figure 5. How teachers made sense of student thinking in discussion forum posts.

If we look at the processes used in the posts across units, posts are identified as "Inferring" 61% of the time in Unit 3, whereas the percentages are lower in Units 1 and 2 (45% and 57%, respectively). Discussion forum posts are also more likely to compare the paper/pencil students to the technology students in Units 1 and 2, whereas only 2% of the posts were assigned this code in Unit 3. This is not surprising since we noted earlier that the posts focused more on technology first two units, and this decreased in Unit 3. Additionally, posts were more likely to compare the students in the video to their own students in Unit 3 (about 11% of the time), than in Units 1 and 2 (about 2% and 0%, respectively).

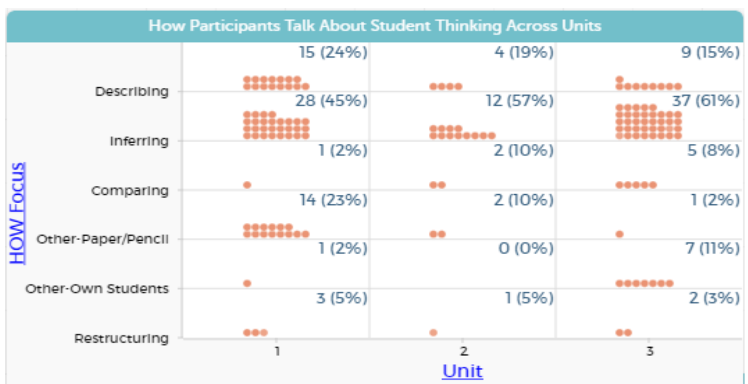


Figure 6. How participants discuss student thinking across units**.**

Discussion

With more content and courses for teachers available online, it is likely that this will be a venue where teachers seek out professional learning experiences. Massive open-online courses transcend geographic distances and time zones to bring people together around a common interest across the globe. With asynchronous MOOCs, teachers can make decisions about when and how to participate. While research provides evidence about how teachers can improve in their ability to notice and analyze students' thinking in face-to-face professional development, little research is available that examines how this transpires online.

Other studies that examined how participants noticed classroom events while participating online found a shift in attention from factors related to classroom implementation to features of the task (McGraw, Lynch, Koc, Budak, & Brown, 2007) or a shift in the sophistication of analysis of student thinking about specific mathematics (Fernández, Llinares, & Valls, 2012).

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Our study provides evidence that in our online course teachers' attention to student thinking increased over time. In addition, teachers' posts provided evidence of going beyond what students were doing with the technology to making inferences about students' thinking. We also found that while many of the initial posted focused on issues related to the technology, this shifted over time to focus on other aspects related to mathematics teaching and learning.

Acknowledgments

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References

American Federation of Teachers (2002). Principles for professional development. Washington, DC: Author. Available: http://www.aft.org/pubs-reports/downloads/teachers/PRINCIPLES.pdf

Borasi, & Fonzi (2002). Foundations (vol. 3): Professional Development That Supports School Mathematics Reform. National Science Foundation.

Darling-Hammond, L., Wei, R. C., Andree, A., Richardson, N., & Orphanos, S. (2009). Professional learning in the learning profession. *Washington, DC: National Staff Development Council*.

Ertmer, P. A. (1999). Addressing first-and second-order barriers to change: Strategies for technology integration. *Educational technology research and development*, *47*(4), 47-61.

Fernández, C., Llinares, S., & Valls, J. (2012). Learning to notice students' mathematical thinking through on-line discussions. *ZDM*, *44*(6), 747-759.

Garet, M., Porter, A., Desimone, L., Birman, B., & Yoon, K. (2001). What Makes Professional Development Effective? Results from a National Sample of Teachers. *American Educational Research Journal, Vol. 38(4)*, 915-945

Loucks-Horsley, S., Hewson, P., Love, N., & Stiles, K. (1998). *Designing professional development for teachers of mathematics and science*. Thousand Oaks, CA: Corwin Press.

McGraw R, Lynch K, Koc Y, Budak A, & Brown, C. (2007). The multimedia case as a tool for professional development: an analysis of online and face-to-face interaction among mathematics pre-service teachers, in-service teachers, mathematicians, and mathematics teacher educators. *Journal of Mathematics Teacher Education 10*(2):95–121

Sherin, M. G., & van Es, E. A. (2005). Using video to support teachers' ability to notice classroom interactions. *Journal of Technology and Teacher Education*, *13*(3), 475-491.

Sparks, D. & Hirsh, S. (1997) A vision for staff development. Association for Supervision and Curriculum Development, Alexandria, VA.

Van Es, E. A., & Sherin, M. G. (2002). Learning to notice: Scaffolding new teachers' interpretations of classroom interactions. *Journal of Technology and Teacher Education*, *10*(4), 571-596.

van Es, E. A., & Sherin, M. G. (2010). The influence of video clubs on teachers' thinking and practice. *Journal of Mathematics Teacher Education*, *13*(2), 155-176.

Wilson, P. H., Lee, H. S., & Hollebrands, K. F. (2011). Understanding prospective mathematics teachers' processes for making sense of students' work with technology. *Journal for Research in Mathematics Education*, *42*(1), 39-64.