Using multi-decision scenarios to facilitate teacher knowledge for mathematical questioning

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A novel method for both examining and improving preservice teachers’ knowledge for facilitating mathematical discussion is presented. The online platform LessonSketch.org was used to create comic-based representations of mathematics teaching that included multiple variations depending on user (preservice teacher) question choice. Each scenario includes three decision points in which question types are available as options for the user, allowing for 39 potential storylines generated from user choice. Preliminary data from preservice teachers is presented, along with an example scenario, to support discussion for implementation in teacher education, with the example provided focusing particularly on elementary mathematics.

Introduction

Over the last several years, approaches to mathematics teacher education have been increasingly informed by indicators of mathematical knowledge for teaching (MKT). Most widely discussed by Deborah Ball and colleagues (Ball, Thames, & Phelps, 2008; Ball & Bass, 2000; Hill, Schilling & Ball, 2004), MKT includes several sub-domains of knowledge that can be usefully distinguished into two primary groups: subject matter knowledge (SMK) and pedagogical content knowledge (PCK). These domains, and their subdomains, have been particularly useful in creating multiple-choice quantitative assessments at the elementary (Hill et al., 2004), middle (Hill, 2007), and secondary level (Herbst & Kosko, 2014), as well as assessments based on representations of practice (Kersting, 2008; Kersting, Givvin, Sotelo, & Stigler, 2010). Such assessments have aided in exploring relationships observed between teachers’ actions and their level of MKT (Ball et al., 2008; Kersting et al., 2010), as well as relationships between teachers’ MKT and their decision-making in hypothetical scenarios (Kosko, in review; Kosko & Herbst, 2012). Part of what makes these assessments both reliable and valid is their construction of items surrounding particular tasks of teaching (Herbst & Kosko, 2014). In the case of assessments following Ball and colleagues’ approach, items are situated in a task specific to mathematics teaching and the participant reading the item is solicited to make some form of decision (is a child’s mathematics correct, do they hold a certain misconception, etc.). However, such a design can be modified to not only assess, but improve conceptions of MKT.
Objectives and Purpose

Tasks of mathematics teaching provide a useful context for assessing and improving teachers’ conceptions of MKT. In this paper, I describe the use of animated representations of practice via an interactive web-based platform (LessonSketch.org) to prompt preservice teachers to consider multiple scenarios of instruction, differing on the premise of pedagogical decisions made in the scenario. To facilitate this description, an example and response data are discussed. Given these objectives, the purpose of this paper to describe the initial efforts of designing these activities for preservice elementary teachers to develop their MKT for the specific task of facilitating mathematical discussions.

Related Literature

Much of the research examining teacher knowledge, in general, and MKT in particular is based on early research on teachers’ decision-making in the 1970’s, pioneered by Alan Bishop, Lee Shulman, and Richard Shavelson through a series of concurrent investigations (Borko, Roberts, & Shavelson, 2008). Such work considered understanding teachers’ decision-making as a means of improving teacher education. Shulman’s (1986) contribution to this line of research was his conceptualization of teacher knowledge, particularly PCK. MKT, developed by Ball and colleagues as an extension of Shulman’s work (Ball et al., 2008; Ball & Bass, 2000), has since been shown to be a useful factor in explaining a portion of teachers’ decision-making (Kosko, in review; Hill, 2010: Kosko & Herbst, 2012). However, items included in assessments of MKT are situated in tasks of teaching (Herbst & Kosko, 2014). These tasks of teaching can serve as simplistic scenarios of classroom practice, often boiled down to a very particular moment in the potential decision-making process. As such, tasks of teaching can be considered as one type of representation or practice.

Representations of practice, in general, have been used in teacher education programs for decades; mostly in the form of written cases and video vignettes. For example, Jacobs, Lamb, and Philipp (2010) describe the use of video vignettes as a means of developing elementary teachers’ noticing of student thinking. However, Jacobs et al. (2010) frame their description of noticing as a part of a process of decision-making on the part of the teacher. Further, the skillset of noticing students’ thinking and operationalizing it within teachers’ decision-making is something that can be learned provided certain experiences. Some have suggested the use of cartoon and comic-based representations as a means of developing such skillsets (Chen, 2012; Chieu, Herbst, & Weiss, 2011; Herbst, Aaron, & Chieu, 2013). Chieu
et al. (2011) found that animations provided prospective teachers with opportunities to focus on particular aspects of instruction. Rather, while videos include all events that occur in a classroom, animations allow for a filtering of certain information and events, allowing for specific features of practice to come to the fore. Chen (2012) examined preservice teachers’ construction of vignettes and found that when preservice teachers created cartoon-based scenarios, they had an increased focus on student actions in lessons.

While cartoon-based scenarios have been found to be useful for facilitating mathematics teacher education, other studies have examined how cartoon-based scenarios can be used to examine teachers’ decision-making (Kosko & Herbst, 2012), as well as how MKT is embedded as part of the process of decision-making (Kosko, in review). The findings from these various studies suggest that cartoon-based scenarios can be used to both improve and assess MKT. Given this background, I extended findings from the literature and applied them to the context of an elementary mathematics methods course. Within the next section, I describe the nature of the comic-based scenarios used, the manner in which they were used, and preliminary evidence for their effect on preservice teachers’ MKT in the context of facilitating mathematical discussions.

Innovative Instructional Practice

Branching Decisions as a Representation of Practice

I use the term branching decision to denote a particular representation of mathematics teaching that includes multiple decision points, and thus multiple branches in a decision tree for a scenario. While it is possible to use various types of representations to create a branching decision (i.e., written cases, video vignettes), Herbst, Chazan, Chen, Chieu, and Weiss (2011) have argued that comic-based representations of teaching offer a more pragmatic means of developing such branching scenarios. In particular, comic-based representations contain many of the visual indicators present in video, but can include hypothetical as well as actual happenings in the classroom (Herbst et al., 2011). Herbst et al. (2011) advocate the use of LessonSketch.org for the creation and organization of such representations, and I elected to follow this recommendation.

In Spring 2014, I developed and implemented two branching decision scenarios into a preservice elementary mathematics methods course early in the semester (n = 20). The course one of two mandatory mathematics methods courses for preservice teachers, focusing on mathematics pedagogy and children’s mathematical thinking. Because the course also places
a large emphasis on number and operations topics, the two branching decision scenarios were designed to focus on multi-digit subtraction and fractions, respectively. Each scenario included three decision points with between three and four hypothetical actions for preservice teachers to consider. Each action depicted the teacher posing a question, structured after Boaler and Broadie’s (2004) descriptions of *gather info*, *generate discussion*, and *probing questions* because of the prevalence these question types are observed in classroom practice. Further, scenarios were designed so that decision branches could be designated as *probing sequences* that included more than one probing question to solicit students’ mathematical thinking (Franke et al., 2009). Preservice teachers could explore alternate decision branches using a ‘back button’ embedded in LessonSketch.org experiences. In this manner, preservice teachers enrolled in the course could examine the consequence of asking certain questions. Following completion of branching decision experiences, we discussed both the question practices, and students’ mathematical thinking within scenarios as part of the next course meeting.

**Classroom Examples**

For purposes of space, I discuss the use and preliminary findings from using the fractions branching decision experience in the fifth week of the course. Preservice teachers completed the experience after one course meeting which focused on Steffe and Olive’s (2010) description of children’s fractional schemes, and ways in which to help students develop particular definitions of fractions. When preservice teachers opened the experience in LessonSketch.org, they were provided an overview of the class, including descriptions of the teacher, particular students, materials, and curriculum at time of the scenario. They were then presented with the initial slides of the scenario, shown in Figure 1. The scenario included use of Cuisenaire rods, which aligned with content focused on in the course meeting, as well as the readings assigned for the preceding and forthcoming week.

![Figure 1. Initial Stem of Example Branching Decision.](image-url)
After viewing the scenario in Figure 1, preservice teachers were provided with three initial options (see Figure 2). Each of these decisions, designated with a dashed border, resulted in different student responses. The first option was classified as a *gather info* question because it solicited only an answer from the depicted student Jessie. The second option was a *probing question* because it asked Jesse to describe the procedures for finding the number between one-third and two-thirds. The final option was a *generate discussion* question as it did not designate a particular student provide a response.

![Figure 2. Optional Decisions for First Decision Point.](image)

Selecting the second option resulted in Jesse briefly describing what she and her partner did to find a solution of three-sixths. However, another student disagrees and says that the number can also be one-half. Figure 3 presents this consequence of choosing the second action in Figure 2. Yet, Figure 3 also presents a portion of a decision path that can result; the second slide in Figure 3 presents another decision point (probing question) and the third slide
presents the consequence of that decision. Should the preservice teacher completing this item continue to choose certain prompts, students will eventually present their full and correct descriptions of their mathematical strategies and solutions (as has been observed by Franke et al., 2009).

In the comments and discussion that followed, preservice teachers noted how comparing the results of different questions affected their teacher knowledge. One preservice teacher, Sarah, noted, “it was interesting to see at which point the teacher moved on the next question. I tried many different options to try and include the most discussion and explanations before moving on, while not forgetting to solve the original problem.” This echoes what many other preservice teachers noted was a tension regarding attending to students’ mathematical thinking, while also attending to demands of the curriculum (in this case the mathematical task at hand). Another preservice teacher, Megan, commented that “it’s important to dig deep and
encourage children to show their thought process. Instead of moving on to the next problem, we encouraged Jesse to explain why.”

What it meant for preservice teachers to have students “explain why” was a concept that evolved over the entire course. At this point in the semester, Sarah was describing this in terms of using probing sequences while Megan was referring to individual probing questions. Megan’s descriptions were fairly common in the course, but they also demonstrated an improvement in how preservice teachers described facilitating mathematical discussions at the beginning of the course. In completing the first branching decision experience, approximately 60% of the class indicated that using a series of *generate discussion* prompts was appropriate; this effectively limited the depth of mathematical description in the depicted scenario in exchange for a larger number of participating students in the scenario. Rather, by examining the various branches in each depicted scenario, and being instructed to focus on how the questions helped students articulate their thinking, preservice teachers began to make more meaningful connections between the nature of a mathematical prompt and students’ mathematical descriptions. Anna’s description, below, helps illustrate this point.

One thing that I learned was you really need to follow along with the story and think about the responses the students will give. When I picked what the teacher should do next, I had a scenario set up in my head, but when I reflected on my story it wasn’t what I expected (Anna).

**Implications**

Use of the branching decision experiences showed the potential for engaging preservice teachers in reflecting on their own MKT in regards to facilitating mathematical discussions. This was in spite of only using two such experiences in the course. Future implementation will include additional experiences with a similar emphasis on focusing on how choice of prompt affects what student thinking was solicited. Additionally, branching decision experiences for other tasks of teaching could be created to help preservice teachers develop their PCK in specific instructional contexts that may not readily come about in their field experiences. However, additional study and implementation is necessary to fully realize the potential of branching decisions in mathematics teacher education. While this paper provides the mere beginnings of such work, it appears there is much promise in branching decisions as a teacher education tool.
Notes

The term *branching decision* was coined by Daniel Chazan and Patricio Herbst in their work with cartoon-based representations of practice.

References


