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Elementary Preservice Teachers' Perceptions of Modeling as a Tool for Instruction

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Abstract: As the standards movement continues to gain momentum in U.S. schools, preservice and in-service teachers need greater knowledge in mathematical modeling to engage PK-12 students in such practices. This case-based research study investigated the perceptions and understandings of modeling for 76 entry-level, preservice elementary teachers enrolled in a mathematics methods course at a mid-Atlantic university. Participants were prompted to define modeling and its application to classroom instruction through open-response questions administered in an online survey. A case-based, phenomenological method was used to code and analyze responses. Most preservice teachers expressed a very limited definition or understanding of modeling or how models are used to promote conceptual understanding of problems, systems, or phenomena in mathematics. The nature of the misconceptions and limits in understanding inform ways that higher education might approach the instruction of modeling in mathematics methods courses to develop such knowledge in future elementary teachers.

Purpose

Modeling, simulation, and visualization can be powerful instructional tools to teach about phenomenon, systems, and events in science, technology, engineering, and mathematics (STEM). Current U.S. education standards in mathematics, science, and engineering emphasize modeling as a professional practice to be developed in PK-12 students (National Governor's Association, 2010; Next Generation Science Standards Leads States, 2013). In general, this specific practice promotes the concept of learners developing and using models to solve significant problems focused on real-life situations, society, and workplace.

If students are to be successful in achieving modeling standards, then teachers must understand critical components and guide them throughout this process. Doerr (2007) raises the issue as to the knowledge that teachers need to be effective in integrating applications and modeling into classroom instruction. She promotes the notion that preservice teachers need to have experiences in modeling that consist of a range of contexts, tools, and analyses of the modeling task (2007). For the current research study, we focus on elementary preservice teachers' understanding of modeling and how it is integrated into teaching and other professional work.

Background

The importance of modeling is accepted in the field of mathematics education. With the standards movement in mathematics (NCTM 1989, 2000; National Governor's Association, 2010), one of the process standards, problem solving, has strong ties to modeling. NCTM (2000) presents problem solving as a process standard where instructional programs from PK-12 should enable all students to:

- Build new mathematical knowledge through problem solving;
- Solve problems that arise in mathematics and in other contexts;

- Apply and adopt a variety of appropriate strategies to solve problems;
- Monitor and reflect on the process of problem solving (p.52).

Such experiences do not just happen without careful planning and insight by the teacher. His/her role is critical to this experience and impacts how students engage in the process of mathematical modeling and associated problem solving. Teachers need to be equipped with the knowledge and skills to engage students in the modeling process to support productive learning environments.

Research in the field of modeling as a tool for learning in STEM has been most visible in the secondary school arena. The purpose of this research was to identify ways preservice elementary teachers define modeling and how they conceive it as part of their future teaching responsibilities. With the push for teachers to engage students in active process standards, this study sought to understand how future elementary teachers conceptualized modeling and gained expertise in such mathematical practices to help them in their future teaching careers.

Perspectives and Theoretical Framework

This case-based research study investigated the perceptions and understandings of modeling for a group of preservice elementary teachers enrolled in a mathematics methods course at one university. Mathematical knowledge for teaching – consisting of content knowledge and pedagogical content knowledge – (Shulman, 1986) was used as a theoretical framework for this inquiry. In addition, the framework of mathematical knowledge for teaching (Ball, Hill, & Bass, 2005; Hill, Schilling, & Ball, 2004) was used to interpret the work involved in teaching mathematics – or in this case, teaching modeling.

Research in the field of modeling has spanned across education from students to teachers but is currently receiving a new wave of attention with the Common Core and Next Generation standards (National Governor's Association, 2010; Next Generation Science Standards Leads States, 2013). Teachers need practice in developing mathematics knowledge so they can incorporate modeling into classroom instruction. In a case study of three future teachers (Kaiser, Schwarz, & Tiedemann, 2013), various levels of knowledge related to modeling emerged. In this instance, it was found that subject matter knowledge impacted the way these future teachers thought about modeling in mathematics. These perspectives certainly had an impact on what these future teachers knew about modeling and how these perspectives would be transferred into the classroom learning environment (Kaiser et al, 2013). Our research was interested to study entry-level understanding of modeling and how such perspectives might work into future classroom instruction.

Preservice teachers have limited exposure to mathematical modeling in either STEM content courses or their teacher preparation program. This is perhaps even more pronounced for the elementary teaching population. This research sought to add to the literature base and to inform teacher preparation programs on issues related to educating future elementary teachers to incorporate modeling in mathematics instruction.

Methods

This case-based research study adopted a qualitative, phenomenology method (Creswell, 2007) to address the following research questions:

1. How do elementary preservice teachers enrolled in a mathematics methods course define modeling?
2. How do their definitions influence their interpretation of how modeling is used in teaching? In other professions?

Context and participants

This research was conducted in a single semester at a four-year public research university in the mid-Atlantic region of the United States. Data were collected from 76 elementary preservice teachers enrolled in an elementary mathematics methods course. Participant volunteers completed a survey that was designed to identify

preservice teachers' perceptions and experiences in modeling and simulation across the curriculum. They were offered extra credit for their participation.

Data sources

Data for this research were collected from a comprehensive survey on preservice teachers' modeling and simulation experiences across the curriculum. For this specific paper, researchers focused on responses to the modeling component and how preservice elementary teachers define and perceive modeling in the teaching profession and other types of professional work. Defining and addressing ways modeling is used was just one piece of the larger survey and is the only section reported here. Preservice teacher participants were asked to define modeling, describe how modeling is used in the teaching profession, and how it is used in professions other than teaching. These questions were posed as narrative/open response items where they were encouraged to elaborate on their answer.

Data analysis

Researchers collected data through three open-response questions administered using an online survey program and analyzed them using phenomenological methods described by Creswell (2007). As required by this method, the researchers suspended prior beliefs, perceptions, and knowledge of how preservice elementary teachers may perceive modeling to objectively understand the definitions of modeling provided by preservice teacher in their responses. It was particularly important for the researchers to acknowledge their experience in mathematics, K-12 education, and with working knowledge of modeling in a variety of contexts. Analysis consisted of review of all comments for the essence of their meaning categorizing them into themes for each question within the frameworks of technological and pedagogical content knowledge (Shulman, 1986) and mathematical knowledge for teaching (Ball, Hill, & Bass, 2005; Hill, Schilling, & Ball, 2004). Themes were validated between the two researchers and comments were reviewed again to authenticate their essence and code individual comments for meaning. Within project validation was accomplished through review of additional research data including other survey items and observations of an in-class modeling project.

Results

Results suggested the elementary preservice teachers had very limited views of modeling that was restricted to modeling as a visualization tool. A limited few participants described modeling as a process with the ability to manipulate variables to understand underlying phenomena. Common themes and specific examples associated with each of the research questions are presented below.

1. How do elementary preservice teachers enrolled in a mathematics methods course define modeling?

The majority of the preservice teachers thought of modeling primarily as using concrete materials such as visuals or manipulatives in classroom instruction. Typical responses included:

- *"Modeling is using materials to turn something in your brain onto the paper or physically in front of you."*
- *"Modeling is being able to show how to solve a problem using different manipulatives to show how you received the answer."*
- *"Activity using real-life examples or manipulative to teach a concept."*
- *"Modeling is using real life examples or manipulatives to solve a problem. It's more interactive that just solving a word problem."*

Almost half of the preservice teachers conceived that modeling involved showing or using a classroom demonstration. Some examples were:

- *"Showing something for someone to follow."*
- "*Modeling is showing other students the correct way to solve a problem."*
- *"Modeling in my own words is teaching through actions."*

- "*Modeling is the teacher or peer demonstrating how to do a task such as adding fractions by using materials such as pattern blocks. It could also be a teacher demonstrating problems on the* board."

Only four teachers focused on modeling as an activity where students are presented with "real life" problems that allow various ways to approach solving the situation at hand. As a group, participants saw the models as a way of "showing" students how to do the mathematics – using a model or visual to see how to solve a problem. These few preservice teachers saw modeling as a process that included investigating real problems to develop mathematics knowledge. Only one participant articulated a more refined definition of modeling by stating, *"Models are used to make connections to real world things and promote critical thinking."*

2. How do their definitions influence their interpretation of how modeling is used in teaching and other professions?

Almost all preservice teachers expressed a limited view of how modeling is incorporated in teaching practices. Examples focused on the use of objects, manipulatives, and demonstrations to illustrate ways of representing content. The majority of these were static in nature and provided neither dynamic nor digital visualization, manipulation, or interpretation. They expressed a better understanding of modeling in other "non-teaching" professions that included more intermediate perspectives, although still lacking in the qualities that make modeling an in-depth and dynamic process.

Participants identified ways models are used in teaching:

- *"They are used by using physical objects such as rulers, pattern blocks, geo boards, doing science experiments so that a student can see how something works. For example, bouncing a ball to show the law of gravity, showing that if the ball goes up it must come down."*
- *"Models are used by teachers to show the students different strategies and ways to look at things that may be difficult to them. Just telling a student something may not work so it would be very helpful for them to be hands on to see how something is done?*

Participants identified ways models are used in the other professions:

- *"Models are used in professions other than teaching to make representations of buildings, prototypes or first drafts of clothing, etc. You can use them to represent different things like amounts of money or population when working in that profession."*
- *"Models are used in order to show and educate other professionals on new ideas, such as business models, workflow models, and models outlining a new experiment."*
- *"In science, models are used to represent molecules. In architecture, a model is used to represent buildings. In finance, models are used to represent information."*
- *"Models are often used in other professions to ensure people learn how to do something successfully."*

While the collective conception of modeling in teaching involved demonstration and use of visual representations, preservice teachers in our study expressed the notion that modeling in other professions allows one to connect or represent a pattern or configuration of some phenomenon. Almost one-third of these connections were related to more complex contexts of understanding, manipulating, and forecasting. The overall conception of modeling in other professions was more complex and sophisticated than their understanding of modeling in education.

Implications

As the standards movement continues to gain momentum in U.S. schools, preservice and inservice teachers need greater knowledge in mathematical modeling to engage PK-12 students in such practices. How teacher knowledge is developed and acquired requires more research of pre- and inservice teachers (Doerr, 2007; Dugdale, 1994; Lingefjard, 2002; Zbiek, 1998). This work is important to providing insight regarding how higher education

might approach the instruction of modeling into mathematics and mathematics methods courses to develop such knowledge in future elementary teachers. Suggestions include two related points that programs may focus on.

The first point involves taking steps towards the technological experiences teachers are exposed to in their STEM content and educational methods courses. More coursework or professional development opportunities should engage both university faculty and K-12 teachers in using technology to develop models of specific phenomena under study (growth, patterns, collection of data, etc.) to ensure that future teachers encounter effective use of modeling in their own STEM learning. Research has already shown that teachers often need to experience such learning techniques themselves to consider ways to incorporate them into classroom instruction (Borko & Putnam, 1996; Lortie, 1975). Real problems with visual representations lend themselves to inclusion of modeling with technological tools. Universities need to support teachers in identifying "appropriate" problems that exist and how to present them to young learners while covering required curriculum.

Second, while the use of appropriate representative problems is vital to modeling experiences, it is also important that teachers develop technological literacy in using appropriate tools. The technology field has grown from the days of graphing calculators and "canned" computer programs to that of interactive applets and programs (e.g., PhET, Shodor, Excelets, STELLA, etc.) that model specific phenomena under study. Teacher preparation programs have a responsibility to support teachers in learning and implementing valuable tools in the classroom and ensuring that future teachers understand the power of these tools drawing from their own learning experiences across their K-12 and university curricula.

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