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Preservice Secondary Mathematics Teachers' Reflections in Using Excelets as a Tool for Modeling

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Abstract: With widespread adoption of technology for all into schools across the U.S., teachers need to be prepared to integrate these tools into classroom instruction. For mathematics, modeling problems with technology provides a key opportunity for students to experience the active nature of such tools in making sense of mathematics concepts. In order to gain insight into incorporating these tools into modeling tasks, preservice teachers need exposure to them as along with reflection on their use. This case study of 12 preservice secondary mathematics teachers enrolled in a mathematics methods course focused on a modeling task that was presented in an Excelet. Participants went through the Excelet and then reflected on the experience they had in interacting with it. Data included a video-recording of participants thinking-aloud while working through the Excelet and a survey consisting of 10 Likert-type and 5 open-ended questions where they reflected on their experience. Findings indicate that by reflecting on the experience related to using this tool, preservice teachers gained insight into challenges in integrating technology within content instruction. Participants fell into categories of strong or weak reflective individuals crossed with strong or weak users of technology. Findings of this study provide more evidence that teacher preparation programs still have work to do in preparing mathematics teachers to integrate technological tools into classroom instruction.

Background and Purpose

With the Common Core State Standards – CCSS (National Governors Association, 2010) movement across the United States (U.S.), teachers are expected to engage students in actively "doing" mathematics rather than passively "receiving" mathematics. Such learning experiences include making sense of problems, reasoning, modeling, and using appropriate tools to explore and solve problems. These mathematical practices are to be adopted for all students, but how teachers develop these practices and incorporate them into their teaching is an unclear path. The Conference Board of Mathematical Sciences' (CBMS) *Mathematical Education of Teachers II* (2012) professed that future mathematics teachers should have experiences and opportunities to struggle with hard problems, discover their own solutions, and reason and model mathematically throughout their coursework so that they possess the skillset to incorporate such processes and practices into future instruction. In addition to the CCSS and the *MET II*, teacher preparation programs should heed the recent *Standards for Preparing Teachers of Mathematics* – SPTM (AMTE, 2017) and address ways of accomplishing these standards as a part of every future mathematics teacher's training and education.

Modeling tasks provide a fertile environment for preservice teachers to investigate "real-life" mathematics and benefit exploring and learning concepts differently by use of technological tools. We believe that preservice teachers must experience modeling activities themselves before they can transfer the ideas of mathematical modeling into future instruction. Doerr (2007) echoes this position by asserting that preservice teachers need to have experiences in modeling that consist of a range of environments, technological tools, and analyses of modeling scenarios. It is the act of analyses, involving some level of reflection, which has long been established in educational literature as relating to the development of teacher practices. It was this analysis of work in modeling – more specifically the reflection of those experiences – that was of interest to this study. In this paper, we focus on the

element of reflection, which is one part of a larger modeling study on preservice secondary mathematics teachers (Enderson & Watson, in progress).
In 2006, the Association of Mathematics Teacher Educators (AMTE) published a technology position statement recommending that preservice teachers have opportunities to:

- Explore and learn mathematics using technology in ways that build confidence and understanding of the technology and mathematics;
- Model appropriate uses of a variety of established and new applications of technology as tools to develop a deep understanding of mathematics in varied contexts;
- Make informed decisions about appropriate and effective uses of technology in the teaching and learning of mathematics; and
- Develop and practice teaching lessons that take advantage of the ability of technology to enrich and enhance the learning of mathematics (p. 2).

Exploring modeling scenarios that involve use of Excelets provides opportunities for these action items to occur with strong connections between content and technological tools.

Enderson & Watson (in progress) researched the use of an interactive spreadsheet tool programmed in Microsoft Excel, called an Excelet, to explore mathematical concepts centered around modeling. The purpose of the study was to identify ways preservice secondary mathematics teachers solve modeling problems and their views and methods of integrating modeling into future instruction. Excelets are interactive spreadsheets created in Microsoft Excel that allow for simulation, visualization, and exploration of mathematical models (Sinex, 2005). Excelets offer an interactive, graphical interface with a variety of input options and data displays. While there is research in the use of spreadsheets in mathematics education, there is limited research in using Excelets.

In order to prepare teachers to engage students in "real" modeling scenarios as well as supporting the technology position statement (AMTE, 2006), one must experience and engage in such cases and then contemplate on the process. Thinking about the tool(s) used to develop an understanding of the concepts involved requires the process of reflection. This act of reflection is not a newcomer to the field of education. Dewey (1933) promoted this process as one of the modes of thought – "active, persistent, and careful consideration of any belief or supposed form of knowledge in light of the grounds that support it and the future conclusions to which it tends" (p. 7). Rodgers (2002) also identified Dewey's criteria for reflection as:

- a meaning-making process that moves a learner from one experience into the next with deeper understanding of its relationships with and connections to other experiences and ideas.
- a systematic, rigorous, disciplined way of thinking, with its roots in scientific inquiry.
- one that needs to happen in community, in interaction with others.
- one that requires attitudes that value the personal and intellectual growth of oneself and of others (p. 845).

It was these noted measures of reflection that were precisely what researchers were interested in studying as it applied to preservice secondary mathematics teachers.

Framework and Research Questions

Reflection is an important action for preservice mathematics teachers to carry out when engaged in modeling tasks using Excelets (or other tools) as well as how the teachers think about the process they go through in trying to answer guiding and related questions. Dewey (1933) and Rodgers' (2002) work on reflection provided researchers with a framework to guide the focus on reflection in the current study. By connecting concepts and ideas through the use of dynamic technological tools, one must analyze his/her thinking about the mathematical concept, how the tool is used to explore the concept, and the degree to which the technology made things easier, better, more visual, etc. All of these points – whether thought in isolation or revealed as part of a community of learners – provide valuable insight into one's practices related to modeling.

This case study on preservice secondary mathematics teachers adopted a qualitative method (Creswell, 2007) to address the following research questions:

1. *How do preservice secondary mathematics teachers enrolled in a mathematics methods course reflect on their use of technology in exploring a given mathematics concept?*
2. *How does the reflection process align with the modeling artifact that preservice teachers produced?*

In what follows, we present the methodology of this study, along with the findings and implications.

Methodology

Participants & context

This research was conducted in a single semester at a four-year public research university in the mid-Atlantic region of the United States. The study employed a qualitative design approach with participants who were preservice teachers completing a secondary mathematics teacher preparation program where they would gain licensure to teach middle or high school mathematics. Participants consisted of 12 students enrolled in a secondary mathematics methods course; 4 graduate level, 6 undergraduate level, and 2 post-baccalaureates (non-degree where one gains licensure only). In this course, preservice teachers often were presented with scenarios steeped in content where pedagogical practices were explored and discussed. One area of focus was on using technology as a tool for exploration and developing an understanding of concepts. The program embraced the notion that preservice teachers need support in integrating technological tools into instruction of content and thus, Excelets was one tool that was used in modeling mathematical concepts. One of the researchers was the instructor of the methods course and designed the course in a way to address both content and pedagogy simultaneously. Technological tools provided an excellent approach to study and integrate these two areas in novel ways for preservice teachers.

Instructional tasks & data sources

The instructional task completed for this study consisted of an independent assignment where students were given instructions to complete a modeling task using an Excelet. They were first asked how well they knew how to use Excel and were provided with links to a reference booklet and a tutorial, which provided instructions on the use of needed competencies for Excel use in the lesson. Then they were given instructions to access and either run or download the Excelet, "Investigating the height of a stack of cookies" (Sinex, 2011) and to complete a worksheet with guided mathematical modeling tasks. They were asked to "think aloud" as they completed the modeling task and to videotape their computer screen throughout the interaction. This recording was submitted, along with the worksheet and reflections, as part of their final assignment submission. After completing the modeling task, they were asked to complete a reflection handout posted in the learning management system which required them to process, think, and react to the modeling task and experience. The assignment was required for the course. Participants were given the option to opt out of study participation such that their data would not be stored or analyzed as part of this study. All study data were linked prior to de-identification using a unique identifier. Analysis was conducted after conclusion of the semester to ensure that neither data nor participation affected the course grade.

As was previously identified, participants in this study interacted with the "cookie stack" Excelet (Sinex, 2011). This Excelet consists of four worksheets with (1) an overview and objectives for using the Excelet, (2) exploration of the linear relationship between number of cookies and the height of the stack of cookies, (3) variations in the height of cookies on linear error, and (4) error in the ruler used to measure the cookies. The interface consists of a linear graph plotting the number of cookies and height of the stack. Each interactive worksheet contained an interactive graph and questions to guide the exploration. Figure 1 illustrates one of the worksheets for the "cookie stack" Excelet.

Data consisted of the brief survey participants completed after going through the cookie stack modeling scenario (for more details on this Excelet, see Watson & Enderson, 2018). This researcher-developed instrument consisted of 10 Likert-type items where participants rated their reflections as low (1) to high (5) to qualify the ease and difficulty of completing the modeling task, using the technology, and making connections between the content presented in the Excelet and the underlying mathematical model. The survey also included five open-response items where participants reflected on their understanding and comfort level with the task, connections of this task to STEM, and any perceived barriers to completing the task. Data also included an individual video recording of each student "thinking aloud" while exploring and going through the modeling task.

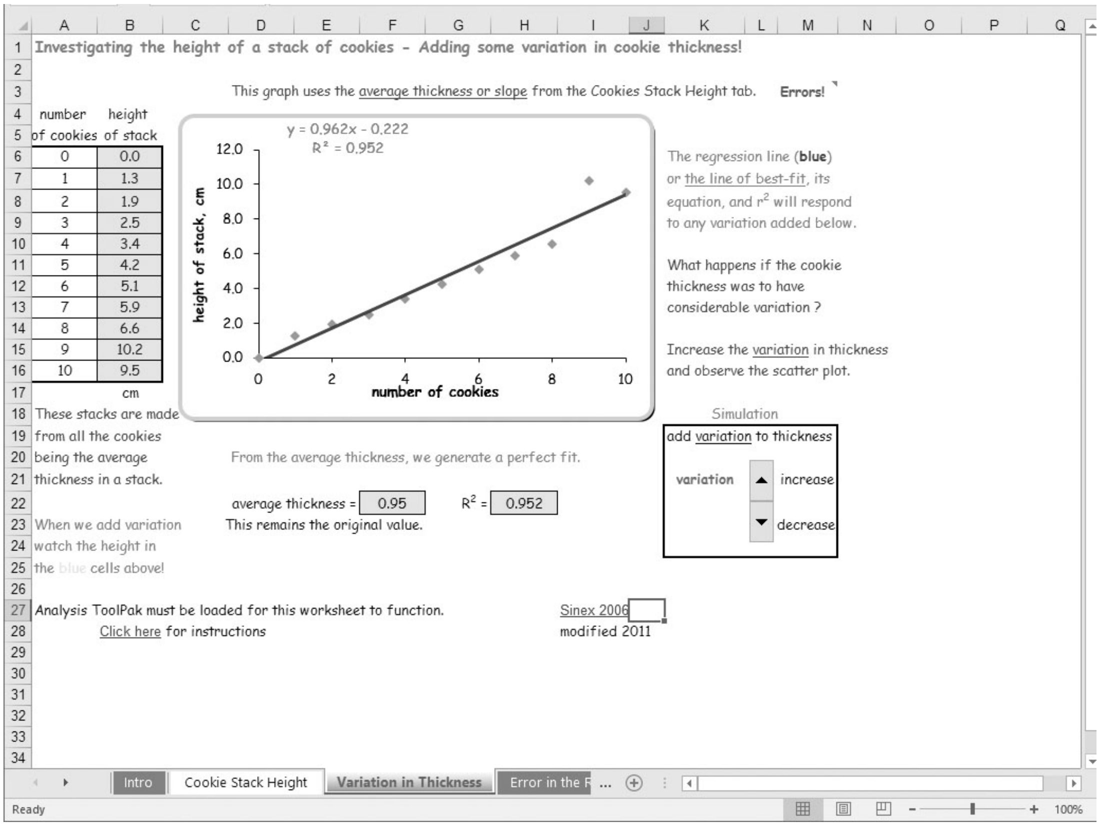

Figure 1: Investigating the Height of a Stack of Cookies Excelet

Data analysis

To assess student interactions with the Excelet, the videos were viewed, transcribed, and coded for themes describing interactions, connections and misconceptions of content and model dynamics expressed during the modeling task, expressed understanding of the model, and ease or difficulties using the Excelet.

The select-response and open-response sections of the reflection survey were analyzed separately. The numeric ratings were coded and analyzed as raw ratings and associated mean for each participant. The five open-ended items were analyzed for themes within each question and interpreted to address the second research question.

Results

The results of this study are reported for each research question.

1. *How do preservice secondary mathematics teachers enrolled in a mathematics methods course reflect on their use of technology in exploring a given mathematics concept?*

Responses to survey items were analyzed to answer this question. Numeric ratings from the reflection survey were coded and a mean of the ten Likert-response items was calculated to determine the overall self-reported benefit of

Excelet modeling activities and associated reflection. Mean scores ranged from negative (low =0) to positive (high=5) and were used to assess the value of the reflection activities and use of the modeling tool. To compare trends across participants, mean reflection scores were plotted along with reported understanding of the content and technology use scores. The resulting plot of all scores are illustrated in Figure 2.

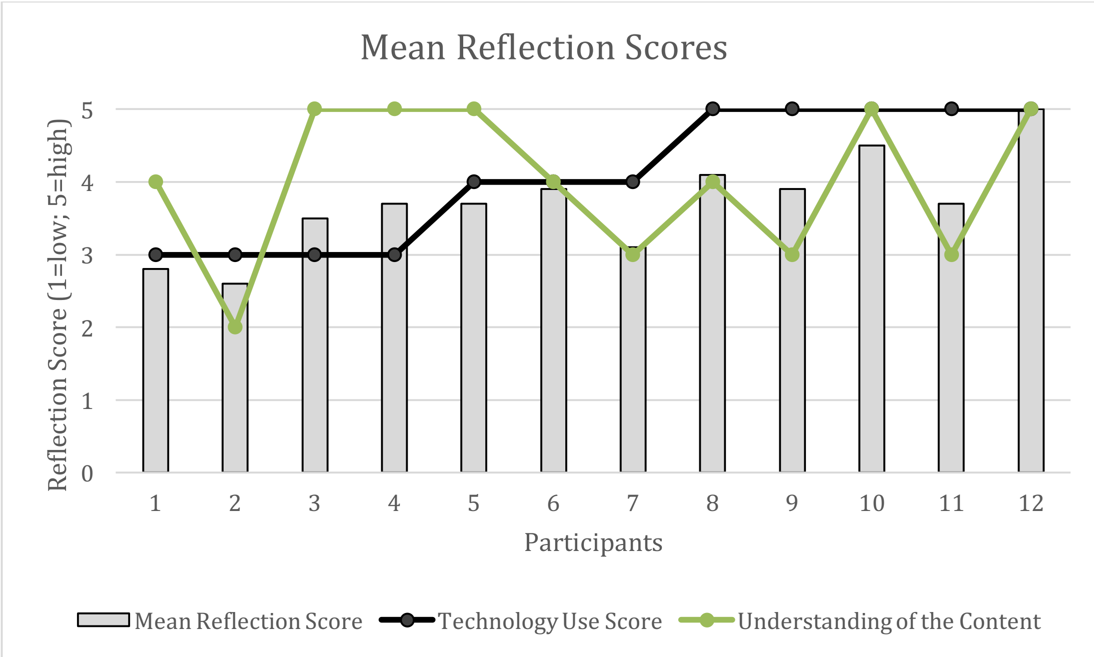

Figure 2: Mean survey reflection scores of participants

The representations of reflection scores and technology use and content understanding shed some light on key ideas in preparing teachers for classroom instruction. In this instance, many of the participants indicate that they understand the content but do not have a high rating of technology use or ease of use. The other side of this phenomena is those who indicate themselves high in their proficiency of technology do not have as high ratings on understanding the content. This point raises the notion of the need to have exposure to technology in mathematics content and mathematics pedagogy coursework before entering classrooms. In many cases, we still see one generic technology course for preservice teachers that catches a variety of majors in it rather than focusing in on tools to use in specific content areas (Niess, 2005). University programs need to take a closer look at this routine and search for ways to make changes in this practice.

In addition, it is important to have preservice teachers reflect on what they carry out in their coursework and what story reflective data can tell us. This specific plot indicates that many new teachers are under-prepared to make valuable use of technological tools (like Excelets) in their future mathematics instruction. How to adjust this reflective data set to illustrate greater success in tool use is what teacher educators should strive for.

To further understand the reflections of participants in this study, results from the open-ended responses were analyzed to assess their understanding of the task, areas where they were comfortable completing the task, and areas where they encountered barriers or difficulties. Approximately one-third of the participants expressed deep and meaningful integration of the task content and the technology, while others reported shallow or incomplete understanding. Approximately one-third of the participants expressed extreme comfort with the mathematics understanding while another third expressed more comfort and fewer barriers with the technology. Comments associated with their understanding, comfort, and barriers are presented here to give a context to how participants engaged and made meaning of the activity.

The following comments were made by participants expressing deeper meaningful integration of mathematics understanding through interaction with the technology:

- *"The purpose of the cookie task is for students to obtain data and for students to use the data in a mathematical model. The questions require students to think about the relationship between the model and the data. Students are also required to make generalizations about changes that would occur to the model as the data changes. The technology helps students reach these generalizations because of the simulations and visuals."*
- *"I understand the role the cookies play and enjoyed not having to compute the line of best fit by hand. For that reason, I feel as if this example would be a great introduction into a unit in statistics focused on variations in measurements and line of best fit. The line of best fit serves for a visual interpretation of the variation of a data sample. More variation will result in fewer data points falling on the line of best fit, whereas less variation will reflect a line of best fit that has most, if not all, data points sitting on the line."*
- *"I understand that we need students to explore concepts in ways that reflect on their learning (old and new) and that technology is a useful tool used to do as such. The task was easy enough to understand and allowed the students to explore a concept with rich questions. I knew that the model be linear in nature because the height of a single cookie is generally the same for each cookie (slight variation) and when stacked, the height is directly varied to the number of cookies."*
- *"From STEM perspective, this task helps students create a system of relationships than just finding a solution to the problem, which I think is more motivating. By being engaged in this interactive/hands-on activity to create relationships, students develop deeper understanding of mathematical relationships."*

The following comments were made by participants whose understanding of the task focused on engaging with mathematics:

- *"The task was to understand a linear model about the positive correlation between the number of cookies and the height of the stack of cookies, as well as the concept of the regression line."*
- *"Task was a good example of using real data to understand relationship between x- and y-values on a coordinate plan and independent and dependent variables."*
- *"I believe I understood the tasks in this assignment; showing how scientific data can be represented mathematically and then investigating how the graph can change by varying the data input."*
- *"The task is having the students explore line of best fit, slope, and equations in slope-intercept form."*

Several participants understood the task to be focused primarily on using technology. Examples of their comments are provided below:

- *"The task showed us how to use Excelets to teach students something., I was able to tell what each new spreadsheet was telling me to do and what operations to perform."*
- *"To utilize technology to explain an idea in the math field."*
- *"The task is measuring and filling in the blank with thought provoking questions."*
- *"My understanding is that students would use this task to explore the concepts on their own. In this case, they are exploring the relationship of data and graphs, slope, line of best fit, and regression using technology."*

Participants expressed their comfort with the mathematics, technology, or both. Several participants expressed their comfort and ease in using the Excelet to complete the task. Others mentioned their understanding of prerequisite knowledge. Several also mentioned the benefits of the Excelet for learning. The following comments are examples of areas where participants expressed comfort in completing the task:

- *"I found Excelets to be an excellent interactive teaching and learning tool to be used for modeling. Excelets can be used for different tasks with different experimental data inputs."*
- *"I feel I have a pretty strong background in Excel, but this is the first time I have used an Excelet."*

- *"Completing the task was easy and motivating. I, personally, like using Excel for creating interactive spreadsheets as they allow users to interact with given tasks which I think is an engaging way of completing any tasks."*
- *"In terms of the material, I was confident. The material requires a background in statistics, and some knowledge on how to interpret a graph. In terms of the assignment as a whole, I like the applications that can be made in a statistics class and an algebra class learning about data points. Having students collect the data gains personal investment into the assignments."*

Participants expressed the following barriers to their completion or understanding of the task:

- *"I think I would need to quickly review regression equations, since I have not seen them in a while. Overall, I think that the task of exploring the Excelet was not too difficult."*
- *"I was comfortable with filling out the worksheet, but the Excelet had a lot of different components to it that I was worried I may press the wrong button and it may mess everything up."*
- *"I was very comfortable at the end of the assignment but kind of irritated in the beginning because I didn't understand what to do."*
- *"But I could see from a student's perspective they could potentially have the barriers of answering the questions because they require some thought and some higher order thinking to answer because you have to think about situations that haven't happened or to think about the problem if certain variables were changed."*

The analysis of reflective comments provides a lens into what participants perceived to be the purpose of the task, their depth of understanding of the task, and the ways that they conceive that the task and associated technology may be used in instruction. Those who were more proficient with both the mathematics and the technology, were also more likely to mention ways that this or similar tools could be used in teaching. They had a richer, more robust understanding of the mathematics, the technologies, and the ways that these come together to create rich, interactive learning experiences. Participants with gaps in either mathematics or technology use did not express such rich understanding. For instance, several participants mentioned that they had not used Excelets in the past and one mentioned that she/he was not experienced with Excel at all. Others mentioned that they were either unfamiliar with the mathematics or that they needed to review the mathematics. Both those uncomfortable with the technology and those unsure of the mathematics focused their cognitive resources on the area where they had gaps requiring more extensive resources for learning and task completion. These individuals did not extend or expand their reflections as extensively into how these technology-enhanced lessons could be used in instructional. Participants who struggled with both technology and mathematics were less likely to make any real meaningful connections between the mathematics, the technology, or the ways that they may be used in instruction. The findings indicate the importance of supporting preservice teachers in providing a variety of learning experiences that allow the exploration of mathematics with technology across a variety of learning experiences. They also suggest that preservice teachers may need a variety of supports to ensure that these experiences strengthen mathematics understanding, promote technological literacy and use, and model sound examples of teaching with technology.

2. *How does the reflection process align with the modeling artifact (evidenced by the think-aloud video using an Excelet) that was produced?*

To answer this research question, recordings of participant interactions with the Excelet were viewed, transcribed, and coded for each participant. This information was used to describe interactions, connections and misconceptions of content and model dynamics expressed during the modeling task, expressed understanding of the model, and ease or difficulties in using the Excelet. Viewing and coding were completed independently by each researcher after which codes were compared and combined to ensure accurate interpretation of each participant's completion of the modeling task. The responses for the five open-ended survey reflection items for each participant were then analyzed relative to the observations of the participant completing the modeling tasks. Themes were derived to explain the behaviors, understanding, and proficiencies demonstrated by participants on a continuum of strong to weak reflection during modeling and use of the technological tools. The resulting observations of behaviors demonstrated are summarized in Table 1.

Participants fell within one of these cells depending on their reflective comments and the degree to which they were successful in exploring and making sense of the Excelet. The descriptors in each cell provide valuable information for coursework involving use of technology, understanding mathematics content, and refining the art of reflection and having opportunities to discuss one's reflection of his/her work.

		Users of Instructional Technology Tools	
Self-Reflection		Strong	Weak
	Strong	• Systematic interaction with all aspects of the Excelet, addressing all guiding questions and prompts • Detailed responses, often asking and answering their own questions • Rich connections between the questions and the mathematical model graphs and variables in the Excelet • Strong connections between changes in variables, visualizations, output, and underlying model • Strong mathematical and model reasoning	• Only the most necessary interaction with the Excelet, addressing all guiding questions and prompts but often answering without interacting with the model • Detailed reflection responses on a few elements represented in the model • Only a few interactions with the mathematical model graphs and variables in the Excelet • Few connections to changes in the variables but strong connections to the possibilities of using Excelets to visualize and interact • Strong mathematical reasoning but model interactions and reason have some gaps
	Weak	• Systematic interaction with all aspects of the Excelet, reading questions and headings but often not answering the questions themselves • Focuses on the technology interactions with proficient use of the Excelet interface but few connections to mathematics or underlaying model • Strong connections between changes in variables, visualizations, output, and underlying model • Strong tool use and tool reasoning but few connections to the mathematics	• Brief interactions with the Excelet, often missing guiding questions and prompts • Simplistic or surface-level responses to questions • Little attention given to the various aspects of the mathematical model displayed in the Excelet • Few or weak connections between variables, visualizations, output, and underlying model • Little mathematical or model reasoning

Table 1: Noted behaviors of reflective task

Implications and Conclusions

This research study, which made use of Excelets to explore a modeling task, brings forth the critical nature of the reflection process. One of the many challenges in preparing teachers for today's classrooms is that university programs talk about reflective practice, but often do not put it into action for preservice teachers. Teacher preparation programs should look for ways to incorporate reflection early in their programs so that preservice teachers can make sense of how newly attained knowledge comes to shape their own understandings of concepts and helps develop their own teaching philosophies and practices (Rieger, Radcliffe, & Doepker, 2013). It is not unusual to find that preservice teachers do not know what to reflect on so they focus attention on recalled points from observations and teaching procedures with little regard for critical insight or reasoning for making certain choices (Risko, Vukelich, & Roskos, 2002). Programs need to give attention to developing greater insight into what is important for teachers in becoming reflective practitioners.

Jaeger (2013) addresses some of the challenges in trying to develop new teachers' use of reflection and proposes that programs need to present activities that promote the reflective practice including reading case studies, writing journal entries, conducting self-studies, and audio- or video-recording and analyzing of lessons. All of these methods have been identified in various ways throughout the literature, but for this particular study, authors focused more on the case study method where participants focused on a specific Excelet and the questions that were used to guide the investigation. Such analysis focuses on decisions made in the moment and can lead teachers to more meaningful ways to reflect on decisions they made and why and whether there were other options that could have been more fruitful in the outcomes of the investigation. This type of instructional activity is valuable on an individual level as well as a group level in communicating one's perspectives and what was seen as important in the case under study.

In this study, the video recordings of participants' "think alouds" provided evidence that preservice teachers need to have more experiences in reflecting on their own understanding of mathematical concepts and particularly where they integrate technological tools that are unfamiliar to them. It may be found that while some preservice teachers understand the mathematical concepts, they may not have a good understanding of how the tool can enhance the development of specific concepts for middle and high school students. In addition, research may find that some tools are better than others to utilize for various modeling explorations. The Excelet tool may have connected with some participants in this study, while others may have been more successful with a totally different tool to use. Regardless, it is important to expose preservice teachers to a variety of tools that can support investigating and exploring various mathematics concepts followed by reflecting on the experience in learning concepts and thinking about ways to present them to middle and high school students.

Lastly, while there is consensus on developing the process of reflection throughout a teacher preparation program, how to successfully carry out this progression in courses that incorporate content learning technologies is not always a direct path. Instructors should be systemic in providing situations for preservice teachers to analyze their own work for strengths and weaknesses as well as share it with others when exploring mathematical concepts using technology. Teacher educators should provide opportunities for preservice teachers to reflect on their feelings and beliefs about use of technology in mathematics and what impact they may have on planning and instruction for their future student-learners. Through the art of reflection, one learns more about him/herself as a teacher and the needs of his/her students, which in turn aids in successfully carrying out valuable instruction that incorporates use of technology needed for today's classrooms.

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