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Preservice Secondary Science Teachers' Reflections in Using Modeling & Simulation Applications as Instructional Tools for Learning

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Abstract: Preparing preservice teachers to construct learning environments integrating technological tools is a challenge that higher education continues to tackle. One way to address this challenge is to have preservice teachers integrate modeling & simulation (M&S) tools while teaching, reflect on the experience, and attempt to identify ways to make improvements in instructional practices. This case study of five preservice secondary science teachers, enrolled in a course along with student teaching, was designed to study M&S tools integrated into instruction and how preservice teachers thought about the experience. Participants taught at least one lesson integrating M&S tools where they were to respond to reflective questions on the application as well as ways to improve the lesson. Findings indicated that preservice teachers fell into a strong or ineffective category in reflecting, which also impacted observations about the tool selected for instruction. This study also identified science teacher preparation programs need greater emphasis in use of M&S tools.

Introduction and purpose of study

Teacher preparation programs across the United States (US), are constantly searching for ways to improve the training of teachers to enter today's classrooms. This is especially true for STEM fields where the *Common Core State Standards* (National Governors Association, 2010) and the *Next Generation Science Standards* (National Research Council, 2013) have been developed to identify what students should know, as well as the tools and processes used for learning. Specifically, in the field of science, teaching based on the *Next Generation Science Standards* "calls for more student-centered learning that enables students to think on their own, problem solve, communicate, and collaborate—in addition to learning important scientific concepts" (National Research Council, 2017). This also aligns with the *Common Core State Standards* (National Governors Association, 2010) for mathematics, where teachers are to engage students in actively "doing" mathematics which involves making sense of problems, reasoning, modeling, and using appropriate tools to investigate and solve problems. While such instructional practices are to be adopted for all students, how science and mathematics teachers develop these practices and incorporate them into their teaching is often unpredictable and not well established.

Modeling and Simulation (M&S) tools are valuable in supporting STEM standards but often are difficult to put into practice for new teachers. The challenges seem to be lack of exposure in teacher preparation programs as well as textbooks and curricular materials used for secondary instruction. M&S tasks provide a rich environment for preservice science teachers to investigate "real" science problems and benefit exploring and learning concepts differently by use of technological tools. It is this researcher's position that preservice teachers must experience M&S learning activities themselves before they can transfer the ideas of M&S into their own instruction. Analyzing and reflecting on learning experiences have long been established in educational literature as relating to the development of teacher practices. It was this analysis of work in M&S – more specifically the reflection of those experiences – that was of interest to this study.

The National Science Teachers Association (NSTA) recommends teacher preparation programs provide various experiences for preservice teachers (NSTA, 2017). Specific to this study is where preservice teachers engage in meaningful laboratory and simulation activities using contemporary technology tools followed by reflecting on the processes (NSTA, 2017). Thinking about the tool(s) used to help develop an understanding of the concept involved requires the process of reflection, which supports Science Teacher Preparation Standard 6 (Professional Knowledge and Skills), which states, "Preservice teachers will engage in critical reflection on their own science teaching to continually improve their instructional effectiveness" (Morrell, Rogers, Pyle, Roehrig, Veal, 2020). It is

this process of reflection that was the focus of this study. Reflection has a long history in education where Dewey (1933) discussed it as a mode of active thought and Rodgers (2002) embraced 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 requires attitudes that value the personal and intellectual growth of oneself and of others (Rodgers, 2002, p. 845).

These noted measures of reflection were precisely what the researcher was interested in studying as it applied to preservice secondary science teachers.

Framework and Research Questions

The motivation for this study was situated in prior research involving preservice secondary mathematics teachers (Enderson & Watson, 2020) and their use of Excelets (Sinex, 2005) as a tool for learning. This study identified some of the challenges in carrying out instruction using Excelets that emerged from participants reflecting on their work (Enderson & Watson, 2020). Reflection is an important process for teachers to carry out when engaged in the use of technological tasks as well as how they think about the process they go through (Enderson & Watson, 2019b). Dewey (1933) and Rodgers' (2002) work on reflection provided a framework to guide reflection as a focal point of the study reported here. By connecting concepts and ideas using M&S technological tools, one has the potential to analyze his/her thinking about the scientific concept(s), how the tool is used to investigate the concept(s), and the degree to which the technology made things clearer, more interesting, more interactive, etc. These reflective elements provide awareness into the practices of preservice science teachers as they attempt to incorporate technological tools into science instruction.

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

1. *How do preservice science teachers enrolled in a perspectives course while student teaching, reflect on their use of M&S technology tools in exploring specific science concepts?*
2. *How does the reflection process align with the M&S artifact(s) that preservice science teachers integrated into instruction?*

The methods adopted for this study, along with an overview of the results and conclusions, follow.

Methodology

This study employed a qualitative design approach with participants who were preservice science teachers completing a secondary STEM teacher preparation program at a four-year public research university in the mid-Atlantic region of the United States. During the student teaching placement, preservice teachers were required to complete an M&S assignment, which involved teaching at least one lesson in their student teaching placement followed by a reflection of the overall experience. Preservice teachers had the option to not participate in the study such that their data would not be saved or analyzed as part of this research study. Analysis transpired after the semester was over to ensure participant course grades were not influenced.

Participants of this study consisted of 5 undergraduate students – 4 females majoring in biology (pseudonyms Crystal, Jackie, Shannon, and Tamera) and 1 male majoring in physics (pseudonym Kolbe). This group of preservice teachers took a series of STEM education courses as part of their minor in education focused on teaching and learning in science and mathematics where exposure to instruction and tasks involving interdisciplinary concepts and ideas occurred. The STEM preparation program embraced the notion that preservice teachers need support in integrating technological tools into instruction of content and thus, technology integration was incorporated across multiple STEM education courses which is often not the case for science and mathematics teachers. Niess (2005) found that many preservice teachers are exposed to technology in a general sense where the instructor is a generalist rather than a content expert. Instructors of STEM courses referenced in this study are

professionals in science and mathematics education and are familiar with technological M&S applications and tools (such as PhET, Excelets, Geogebra, Desmos, etc.) and their impact on learning.

Each participant selected how they would integrate the M&S tool into their instruction since their student teaching placements were at different grade levels (some middle, some high school, some grade-level specific), with different classes (regular, advanced, International Baccalaureate or IB, etc.), and variations in how school districts organize and teach concepts covered in the respective disciplines. Data sources used for this study included lesson plans with M&S task elaboration, recorded videos of preservice teacher "think -alouds" focused on M&S ideas in the lesson, and reflections of the lesson and how the M&S tool(s) influenced instruction of the concepts. Lesson plan design used the 5E instructional model (Bybee et. al., 2006) promoted throughout the STEM teacher preparation program participants completed. This model includes the five phases of Engage, Explore, Explain, Elaborate, and Evaluate and guides instruction in a way where students are involved in the learning process. It encourages exploration and construction of scientific concepts and ideas and how such concepts connnect to other real-life phenomena or problems (Bybee et. al., 2006).

Participant "think-alouds" carried out while planning and designing tasks to incorporate M&S tools during student teaching were collected and analyzed. Video recordings were viewed and coded for themes describing interactions, connections, and challenges of content and technological tools along with level of ease or difficulty in using the M&S application. In addition, participants completed a reflection protocol that guided them in thinking about how the lesson went, what obstacles they experienced in integrating the technological tool(s), and how they might consider improving the task or lesson with such tools.

Results

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

1. *How do preservice science teachers enrolled in a perspectives course while student teaching, reflect on their use of M&S technology tools in exploring specific science concepts?*

To answer this research question, a framework (Fiorella & Mayer, 2015) guided preservice teachers into thinking more deeply about integration of M&S tools. It consisted of 3 parts which included: What are we looking for? How does the application work? and What are ways we can use the tool to guide instruction? Previous work has explored this learning framework as it applies to M&S tools preservice teachers use as part of classroom instruction and has found it to provide a good reflective tool for novices (Enderson & Watson, 2019a). In addition, a reflective protocol was used to encourage preservice teachers to think about the tool they selected, how students used it, and what they could do to make its instructional integration better the next time.

Two specific categories were identified to make sense of participants' level of reflection in integrating the M&S tools into class instruction – (1) strong and (2) ineffective. Evidence brought out that regardless of the M&S tool used or implemented, the stronger (or more descriptive) the reflection of the lesson was, the more valuable the experience was for the preservice teacher. The "think alouds" provided an opportunity for preservice teachers to hear themselves talk about the M&S application and what value it had in learning new material. In the case of Crystal, a biology preservice teacher participant, she reflected on her "think aloud" for an engineering crops application centered on DNA in genetic engineering selected for her lesson. She shared that the thinking process allowed her to reflect more deeply about the technology and how it enhanced her lesson. In addition, she noted that when integrating the M&S application into the lesson, she was able to see the weaknesses it had when students made use of it. There were questions and challenges students confronted that she had not thought about and believed she would be in a position to plan better next time.

Jackie, another biology preservice teacher, was less successful in her reflection of the M&S application in her lesson on mitosis. While she found good reasons to use the application in this area of instruction (i.e., need technology because cell division cannot be seen with the naked eye), she was somewhat ineffective in her reflection of the tool and how it was useful or not. She did not give much thought to the impact the tool might have on instruction and how students might engage in using it. She was much more about "here's an application I can use for

mitosis and students will enjoy exploring it on the computer." Overall, her perceptions of the act of reflecting were positive, but the actual use of the reflective process was ineffective. It did not appear to have an impact on her selection of an M&S tool and ways to consider using it in classroom instruction.

Another point that emerged from participant reflections in this study related to the availability of technology. Lack of technology posed some challenges in student learning, but overall use of a modeling or simulation application in the sciences, even if just used as a demonstration tool, appeared to benefit student engagement in the learning process. Strong reflections provided greater insight into the tool and ways to consider using it. Weaker or ineffective reflections were more superficial and often more indicative of having students have fun with the M&S application with low regard for learning outcomes.

2. *How does the reflection process align with the M&S artifact(s) that preservice science teachers integrated into instruction?*

Findings revealed that a weaker reflection – shorter, more superficial, not as deep in discussing content matters – typically aligned with a less engaging M&S application integrated into the lesson. This was evident for two of the five participants – Jackie being one of them and identified in research question #1. The responses for the two weak reflections were not descriptive and the M&S applications implemented into classroom instruction lacked in some ways in covering specific content and were more repetitive in nature. Jackie and Tamera both reflected about the importance of technological tools in instruction but did not reflect on how their selection of the M&S tool did not allow students opportunity to further explore and ask more questions about the concepts under study. Students might see results but did not have to really engage deeply with the tool. Clicking and moving items around might reveal some findings but the activity was at a very low level for students to see science in action.

The other three participants were more reflective, which aligned with a better developed M&S task used for student engagement and learning. Crystal fell in this grouping and was noted above for research question #1. Kolbe, a physics preservice teacher, also fell in this group. He was thoughtful in his selection of an M&S tool to use with students to explore projectile motion. Students were to predict how variations in initial conditions impacted a projectile's path and provide explanations for their predictions. They were to engage with the M&S tool to check their predictions and identify how close (or how far) they were. Kolbe reflected on this M&S application and what students got out of this experience. He also reflected on ways to make improvements to the task presented and other questions to explore with this M&S scenario to keep student interest and engagement.

The results to this research question, while not surprising, revealed areas that should receive greater attention in teacher preparation programs. These points are in the discussion and conclusions section.

Discussion and Conclusions

The act of reflection has long been a practice in educational circles. 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 use of case studies, journal entries, conducting self-studies, and audio- or video-recording with analysis of lessons. This study contributes to the notion of how reflection can help one be more thoughtful in selection of technological tools to incorporate into classroom instruction and provides preservice teachers opportunities to hear their own thinking related to use of M&S tasks.

An obstacle or challenge many preservice teachers experience in the act of reflection is that they often do not know what to reflect upon. Thus, attention is placed on recalled points from observations and teaching procedures with little regard for critical insight or thinking behind those choices (Risko, Vukelich, & Roskos, 2002). Teacher preparation programs need to support future teachers in developing awareness into what is important for them in becoming reflective practitioners. The study presented here is a small case where preservice teachers were gaining insight into their own teaching practices by reflecting on their interactions with a M&S application for instruction. Some participants showed growth in their teaching practices by reflecting on the lesson, while others needed more growth in this process.

Teacher preparation programs have an important role in supporting novice science teachers to be prepared for classroom instruction and to look for ways to integrate technological tools into instruction. As Shannon, a biology preservice teacher, stated in her reflection, "I would use M&S tools to bring lessons to life – to hopefully provide them [students] with a deeper understanding of my content." It is such thinking and reflection on one's experiences that new teachers find stimulating and exciting ways to share the sciences in meaningful and beneficial ways with their students. Universities and teacher preparation programs need to guide these future teachers into exposure of technological tools to investigate content strands as well as to reflect on such experiences and the impact on student learning.

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