Simulations in Teacher Education Conference
Short Paper Submissions

Agile Thinking: Deciding to Teach Every Student

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Keywords: science education, teacher preparation, rehearsals, digital simulation, non-digital simulation

Project Overview

Achievement gaps provide evidence that all learners are not given equitable opportunities to learn in U.S. schools. Closing gaps and extending learning depends, in part, on the capacity of teachers to make decisions on their feet to adjust instruction, effectively engaging and stretching every student in every lesson within time and curricular constraints. Given the impact of teacher decisions on student outcomes, our research uses immersive learning experiences to examine teacher capacities to make rapid, flexible, culturally affirming instructional decisions when promoting literacy skills through science instruction with elementary and high school students. We explore how digital and non-digital simulated teacher tasks can be used to measure why and how teachers adjust instruction aimed at increasing engagement and providing optimal challenge for students with diverse learning needs. We apply an instructional decision-making framework called All Learners Learning Every Day (ALL-ED, Bondie & Zusho, 2016) to our simulations, based on cognitive and motivation sciences and culturally responsive pedagogy.

Roleplays and a board game approximating authentic tasks and unpredictable challenges are used to measure agile thinking; the mechanism for deliberate decisions to adjust instruction in response to analysis of teacher perceptions. A dynamic instructional decision-making base of self and cultural awareness and content and pedagogical knowledge frames agile thinking resulting in pedagogy observed in the classroom.

Awareness and knowledge interact to form additional frames such as pedagogical content knowledge and culturally relevant pedagogy. Further, each teacher's awareness and knowledge are in a constant state of development, changing over time. We examine how these frames both support and limit agile thinking shaping instructional decisions aimed at providing equitable productive pedagogy for all learners.

Our study begins by developing a profile of each teacher's base for decision making, including content knowledge related to student literacy skills and pedagogical knowledge related to instructional routines, as well as self- and cultural-awareness. We develop a profile through a survey using validated items from previous studies, two classroom observations using the

Observing Patterns of Adaptive Learning to record teacher practices, and two performance tasks.

The performance tasks are simulations placing educators in a situation where agile thinking is required. The first, a digital simulation using avatars managed through the [Mursion system](https://mursion.com/)[1] (asks teachers to conduct a parent-teacher conference focused on explaining how student's literacy skills will improve through science learning. Second, teachers help a new staff member group her students for a research project in the science class that demands grade level literacy skills. Teachers receive information about the students reading abilities, past performance in science, strengths, and interests. Participants explain the rationale for the student grouping. These simulations represent close approximations of tasks done by teachers. Elements that are not accurate to real-life include decision-making time and the opportunity to enact the situation several times.

Together these measures create a profile of a teacher's instructional decision-making base. We examine the extent that instructional decision-making bases differ among participants and the extent that demographic factors such as years of teaching experience predict knowledge and/or awareness. Then, through the non-digital collaborative board game, we examine how the identified instructional base predicts teacher instructional decisions and engaging in the simulation may impact the instructional decision-making base.

The collaborative board game simulation mimics the implementation of a lesson plan. As the lesson progresses, we assess a teacher's ability to identify students' understanding, assess the need for adaptation, and make the decision to adjust the lesson plan accordingly. Following the game, teachers repeat the student grouping simulation to measure the impact of the board game on making rapid, flexible, and culturally affirming instructional decisions.

Following IRB approval, all science teachers at the research sites will be invited to participate. We will recruit 25 science teachers; 12 elementary (3 at each site), 3 high school (2 science teachers and 1 special education co-teacher), and 10 pre-service. School sites were chosen based on their concern over gaps in reading achievement--particularly students receiving free and reduced lunch--and based on teacher interest in differentiated instruction.

Theory of Action

Given the number, speed, and constraints of instructional decisions, teachers use automatic or reactionary thinking during lessons. Consequently, teachers draw upon teaching practices most readily available in their pedagogical schemas. These practices often carry implicit positive or negative biases and are prone to errors (Kahneman, 2011). Figure 3 displays our model of how teacher thinking leads to equitable productive pedagogy that moves students through barriers to learning established curriculum and beyond.

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[1] Mursion's website can be found here: https://mursion.com/

Simulated teacher tasks provide an opportunity to assess how teachers think with their knowledge and awareness as the decision-making process can be slowed down and made visible. This is distinctly different than measuring, for example, content knowledge in terms of how much a teacher has at their disposal. We are interested in the extent to which teachers think with what they know and their awareness to address dilemmas as student learning unfolds. As noted above, our immersive virtual-based simulations place teachers in a real-world classroom. For example, in our board game participants draw "Listen and Learn" cards and encounter barriers to learning faced by different students in their class. They need to make decisions as to how best to address the barriers while meeting the needs of all students. Teacher receive feedback through a scoring system that shows the impact of instructional decisions on each individual student and the cost of instructional decisions in minutes out of the 45-minute lesson. Teacher thinking is made visible as teachers engage in authentic cost-benefit analysis of their instructional decisions in terms of time and student learning. Together, these measures enable us to assess the degree to which teacher decision making changes from baseline to post-intervention and content knowledge, pedagogical knowledge, and cultural awareness contribute to any variance observed.

Learnings

At this time, we have piloted the teacher survey of self-reported self-regulated learning, instructional practices (choice, mastery orientation, group discussion, and adjustments for access, rigor, and relevance), teaching efficacy, agile instructional thinking, comfort with diversity, and assimilation. The survey items were selected from previous studies and show consistent reliability. In addition, we have piloted the non-digital simulation (board game). Experienced teachers found the simulation to be very realistic. Teachers felt the game increased their awareness of strategies used to respond to perceptions of learning needs. We plan to continue to develop the simulations specifically focusing on the architecture of feedback.

Future Directions

Developing capacity includes several components, with an underlying principle of agency, meaning that participants are actors practicing new knowledge and skills, not subjects passively absorbing information. For this reason, we believe in the use of various types of immersive media (360 video, virtual environments with agents, mixed reality systems like Mursion[2]) to present simulated authentic situations in which teachers must respond by adjusting instruction to provide optimal challenge for all students. Future directions may examine how teacher preparation and professional learning may be personalized to increase capacities of the instructional decision-making base.

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[2] Mursion's website can be found here: https://mursion.com/

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Analyzing the Reaction of Pre-Service Teachers using Simulation to Practice Teaching Math or Science

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Keywords: Science education, mathematics education, teacher preparation, role play, live simulation

Project Overview

Eliciting and responding to student thinking is a vital aspect of instruction; however, classroom interactions often reflect a teacher-centered approach with little opportunity for students to share their thoughts (Michaels & O'Connor, 2015). Educational research has focused on the tools and structures necessary to successfully engage elementary pre-service teachers (EPSTs) in the intricacies of eliciting and responding to student thinking (Lampert, Beasley, Ghousseini, Kazemi, & Franke, 2010; Thompson, Windschitl, & Braaten, 2013; Kazemi, Franke, & Lampert, 2009). Within this work, structures such as Cycles of Enactment and Investigation (Lampert et al., 2013) have been designed to engage EPSTs in deliberate practice of specific teaching episodes in classroom settings. This type of reiterative practice provides opportunities for concentrated feedback on teaching to build EPST's skills and conceptual understanding. Although beneficial to teacher preparation, the resources needed to employ an iterative, practice-based process within teacher preparation programs have proven to be logistically challenging or nearly impossible to offer at institutions with large pre-service teacher populations. One innovative technology to facilitate such practice is virtual simulation software, such as Mursion®, which allows EPSTs to practice interaction with students and receive targeted feedback from instructors. This paper reports on initial findings from a three-year, National Science Foundation (NSF) funded effort entitled Project INTERSECT. Project INTERSECT is engaged in developing a curricular model for math and science pre-service teacher education that expands opportunities to master teacher discourse, and measuring the effects of curriculum change and increased discourse engagement on pre-service teachers' use of discourse.

Theory of Action

Standards for both math and science education serve as a foundation for instruction and are used to inform how educators and students interact with each other while discussing math and science topics. The Common Core Mathematics Standards (CCMS) emphasize the context of mathematical concepts. Discourse is at the center of student expression of understanding of mathematics and science concepts. At each level, the students must engage in discourse surrounding topics in order to engage with the mathematics using the appropriate terms and to demonstrate their understanding of the concepts. The Next Generation of Science Standards

(Lead States, 2013) emphasizes the need for students to construct their own explanations of scientific phenomena that incorporate current understandings of science.

Importance of Discourse in Mathematics and Science Instruction

Scientific and mathematics knowledge is constructed by engaging in the social processes of negotiation and consensus building (Candela, 2005; Michaels & O'Connor, 2015). Learning mathematics is a sociocultural process that allows learners to become participants in discourse (Esmonde, 2009). Learning science also requires students to be engaged in a social context while constructing meaning and building an understanding of scientific concepts (Duit & Treagust, 1998). EPSTs must understand the complexity of leading discourse which includes both conceptualizing classroom discourse and negotiating the sequencing of the talk while also managing student engagement (Lehesvouri, Viiri, & Rasku-Puttonen, 2011). To help EPSTs learn build competence in facilitating classroom discourse and interactions, they need explicit experiences with planning and implementing effective math and science classroom discourse.

Interactive Classroom Simulation Activities-Mursion

Project INTERSECT seeks to advance knowledge regarding design for learning particularly in math and science undergraduate teacher preparation by contributing an innovative, replicable research design that includes a series of discourse tools or Teacher Moves (Chapin, O'Connor, & Anderson, 2013) that pre-service teachers can analyze, practice, and reflect upon to develop competence in facilitating effective STEM-oriented discourse. The theory of situated learning (J.S. Brown et al., 1989) supports that training in a virtual environment should transfer to practice in actual classroom settings. The benefit of Mursion, as an effective teaching platform for educational instructors, is the ability to control the complexity of the teaching environment for pre-service teachers to practice complex instructional strategies.

Number Talks

Number talks are five- to ten-minute classroom conversations around purposefully crafted mental computation problems. These daily exercises are used to build students' number sense and flexibility with numbers. Scenarios were created using number talks with multi-digit multiplication problems (i.e., 12x8, 12x16, 35x4) to strengthen the preservice teachers' number sense and allow them to rehearse facilitation of number talks. Possible student responses to the computation problem were embedded within the scenario and based on research-based learning trajectories. These trajectories with multi-digit multiplication allowed for inclusion of different student strategies and misconceptions.

Science Talks

To prepare their science talk plan, EPSTs use a Page Keeley assessment probe (Keeley et al., 2005). Selected probes are aligned with each disciplinary core idea of the science content courses. The probes include a scenario focused on the disciplinary core idea, related student

misconceptions, and preconceptions. EPSTs use the "Teacher Notes" provided to learn the background information and suggestions for implementation of the probe. Each EPST completes a plan for conducting their Science Talk, which includes research on the content, a discussion map of questions to ask, and designated times to implement talk moves.

Learnings

Personal Reflections

The complete *Number Talk Analysis* involves components that deconstruct the mathematics and pedagogy. To account for the mathematics, EPSTs selected two peer strategies and described student thinking, pinpointed mathematical properties underlying the strategy, and created examples and non-examples of effective use of the strategy. EPSTs used their recorded number talk to assist in this analysis. After the implementation of each Science Talk, EPSTs completed a personal reflection. EPSTs were able to use a video recording of their Mursion experience for reflection. Thirty-eight EPSTs in the mathematics methods course and forty-two EPSTs in the life and environmental science course submitted written personal reflections about their teaching experiences in the ICSA. Reflections were blinded and twenty reflections from both courses, equaling a total of forty, were randomly selected and analyzed. Reflections initially analyzed for common themes within the individual courses of math and science. The initial coding of real-life benefits, the importance of content knowledge, and appreciation of good questions and questioning skills were identified within the individual courses. The second round of coding consisted of combining the reflections from both courses to clarify the themes as being consistent of both groups of EPSTs.

Discussion of Student Perspectives

When discussing the beneficial impacts of the ICSA experience, three sub-themes emerged from both the math and science EPSTs reflections.

1. **Real-life Experiences.** Thirty-six out of forty EPSTs' reflections discussed how the ICSA experience was like being in a "real-life" classroom working with real students. A majority of EPSTs stated that the experience made them nervous. This same sentiment about being nervous and anxious about teaching is often revealed by EPSTs when preparing to go into local elementary schools. One disadvantage of the ICSA environment mentioned by twenty of the math and science EPSTs involved the inability to use hands-on materials within the simulation. The inability to use materials or manipulatives with the avatar students was one aspect that EPSTs mentioned in their reflections as being difficult when adjusting their plans.

2. **Knowledge of Content.** Across content areas, thirty-four EPSTs shared how their experiences provided an awareness of their weaknesses in content knowledge. Majority of these experiences involved student questions that they were not cognizant of how to answer or student solution strategies for which they were not familiar. The experience

with student avatars guided them to analyze the content from a child's preceptive and anticipate questions from the mind of a child. EPSTs' reflections captured how their Mursion experience also motivated them to research and revisit the topics within their talks. Examination of the reflections on the number talks revealed an impact on EPTS' beliefs about the nature of mathematics. For some EPSTs, this was their first-time witnessing students solve a multiplication problem other than with the standard algorithm. One goal of the mathematics methods course is to shift beliefs about mathematics. The ICSA seems to support this shift by echoing the learned coursework through student interactions.

3. **Questioning.** One specific element that was discussed in thirty-one reflections was the impact of questioning on the experience. EPSTs shared that they were now aware that the questions they asked were the force behind how students would share their ideas. In addition to the impact of questioning, several EPSTs attended to the purposes of certain questions or teacher moves. That is, they wrote about using talk moves for particular reasons and therefore showed a more advanced conceptualization of eliciting student thinking. This attention to connections is evidence that within this teaching experience EPSTs are beginning to grapple with not only how to elicit student thinking but how to respond in ways that bring student thinking to the forefront of the discussion.

Future Directions

Teacher preparation programs across the nation struggle with finding opportunities for EPSTs to engage in ambitious teaching throughout their undergraduate studies. These teaching opportunities traditionally take place in local schools or in peer-to-peer role play experiences. This traditional teaching experience still remains one of best ways for teachers to practice their craft, but at times it becomes impractical due to the school schedule, teachers' limited practice time in classrooms for EPSTs, and EPSTs university class schedule. This study has shown ICSAs to be a viable alternative for teacher education programs to engage EPSTs in ambitious teaching. In addition to logistically opening doors for teaching experiences, ICSAs also allow for specific feedback on elements of ambitious teaching. Within the number and science talk scenarios, one of the main focuses was on eliciting and responding to student thinking. Current research on rehearsals have involved cycles of peer-to-peer practice and then implementation in an elementary classroom (Kazemi et al., 2009). This cycle requires extensive resources that are not available to larger teacher preparation programs. The immersive nature of the simulation and the structure embedded in the scenarios creates an opportunity for coaching and enactment within one phase.

Another promising impact of ICSAs is the shift in beliefs about mathematics and science. After their first experiences with the ICSAs, ESPTs were sharing that they were thinking of math and

science in new ways. These experiences not only seemed to shift their thinking it also motivated them to dig deeper and expand their content and pedagogical knowledge. Incorporating ICSAs early in preparation programs may support earlier shifts in beliefs that can further strength development of ambitious teaching.

Lastly, EPSTs were mindful that the ICSAs did not allow for lessons that utilize manipulatives or hands-on learning experiences. While EPSTs need explicit coaching on effective use of manipulatives and hands-on activities, the other themes that emerged from the reflections support attention on other aspects of ambitious teaching before bringing this element into focus. That is, EPSTs grappled with eliciting students' thinking and how to navigate a semi-structured discussion and therefore it seems they need opportunities to practice this fundamental aspect of instruction. In doing so, it seems they were more likely to effectively attend to student thinking when integrating more hands-on experiences and transform instruction to minds-on experiences that do not merely involve doing activities without meaning.

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Approximation of Eliciting Student Thinking in Elementary Science and Mathematics Methods Courses

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Keywords: Science education, mathematics education, teacher preparation, approximation, digital simulation

Project Overview

Over the last few decades, teacher education programs have been criticized for the ineffectiveness in preparing high qualified, competent, and skillful teachers. Emerging consensus has been made that teacher education programs need to center on teaching and learning core practices of teaching. One might argue that field placements offer sufficient opportunities for learning practices, but preservice teachers (PSTs) have opportunities to observe "a limited range of practice" which is varied and selected by an individual mentor teacher. Ball and her colleagues (Ball & Forzani, 2009) call for a practiced-based teacher education program wherein "the work of practitioners" is the center of professional education. Having a similar vision about a practice-based professional education, Grossman and her colleagues (Grossman et al., 2009) explored how professionals engaged in relational practices and identified three key aspects of professional education in those professions: representations of practice, decompositions of practice, and approximations of practice.

Among these three key pedagogies for teacher education, approximations of practice— "opportunities to engage in practices that are more or less proximal to the practices of a profession" (Grossman et al., 2009, p.2058)—are very powerful tool for novices to experience "instructive failure" and experiment with different instructional decisions (Grossman et al., 2009) but are more difficult to be implemented because of challenges in providing authentic and responsive learning spaces (Mikeska, Howell, & Straub, 2017). To approximate teaching practices, researchers have adopted different approaches such as rehearsals (e.g., Ghousseini, 2017), animated classroom stories (e.g., Chazan & Herbst, 2012), videos (e.g., Seidel, Blomberg, & Renkl, 2013), and digital simulations (e.g., Dieker et al., 2014) in teacher education programs.

Our project focuses on approximating one of high-leverage practices—eliciting student thinking—in elementary science and mathematics methods courses using the digital simulation software developed by Mursion in the SIMPACT Immersive Learning Lab. The simulation in elementary science methods course provided opportunities for PSTs, who are in the last course sequence of the multiple-subject credential program while doing a full-day second-semester student teaching assignment, to review the lessons about evaporation and then evaluate student thinking about water evaporations and condensation. The simulation in elementary mathematics methods course provided opportunities for PSTs, who are in the first course

sequence of the multiple-subject credential program without any student teaching assignment, to elicit student thinking about a long division algorithm.

Theory of Action

The digital simulation provides opportunities for PSTs to interact with students in a more authentic and safe environment and to engage in "deliberate practice" in a more controlled setting. Through engagement in the simulation, we expect that PSTs will use careful questioning along the different levels of questions, elicit students thinking about the processes they explored in the lesson, and gently challenge students thinking. The simulation utilizes a "coaching" model that teacher educator and other fellow PSTs offer suggestions and immediate feedback to the PST interacting with the five avatars (Dev, Jasmine, Ava, Savannah, and Ethan). The intended outcomes for digital simulation in our methods courses are to ask more content-specific and open-ended questions, elicit student thinking, facilitate interactions among students, make connections between students' ideas, challenge student thinking, reflect on questioning strategies, develop content knowledge for teaching, and finally make a better instructional decision.

Learnings

Case 1: Addressing Students' Alternative Science Conceptions in Elementary Science Methods Course

The science education literature is replete with studies of the alternative conceptions that people of all ages, from the youngest children in elementary school up to adults pursuing a medical degree, form of the natural world. The body of research in this area has also addressed the specific strategies that teachers can apply to bring learners to more accurate understandings of natural phenomena. An attentive teacher that endeavors to learn of the ideas that children bring related to a topic to their classroom, will most certainly find that at least some of students harbor beliefs that discord with the understanding that science provides us. We know from the research on students' conceptions, that those conceptions must be directly addressed in teaching; a teacher cannot assume that by merely teaching about a topic in science that students will develop more accurate conceptions as a result. One strategy is to engage students around conversations about the phenomena in question. The stimulus for the conversation might be a demonstration provided by the teacher in class, a class discussion following an exploratory activity conducted by students, or the results of a simple pre-assessment.

This simulation focuses on the water cycle which is one of several consistent themes adopted in the course and is addressed in an introduction to the NGSS for California, a sample writing assessment in which PSTs analyze student responses to a writing prompt on the topic, and a concept mapping activity that is once again, discussed in the topic of science assessments. The water cycle is discussed in the context of the various processes involved in the water cycle, such

as evaporation, transpiration, condensation, and precipitation, and how teachers can teach about these processes through classroom inquiry. Two specific conceptions that emerge in the simulation is the existence of water vapor in the surrounding atmosphere (elementary school students have a difficult time grasping the notion that there is water vapor in the air around us – at least on days with some relative humidity) and that water that condenses on a cold glass of water or soda condenses out of the surrounding atmosphere rather than travel through the vessel walls to the outside of the container. A typical situation involves five PSTs in the 30-minute conference session. The first PST reviews the previous day's lesson on the process of condensation in which students observed water vapor from a beaker of hot water condensing on a cold surface, and water vapor from the surrounding air condensing on the outside of a beaker of ice water; the second PST elicits students' thinking about the lesson and the ideas they hold or have developed as a result of the lesson. The other three PSTs in the tag-team as teachers working with the specific ideas students have formed as a result of or in spite of the previous lesson.

Upon completion of the simulation, all participating PSTs completed a short reflection in which they discussed the benefits of the simulation to their learning about how to elicit and respond to students' thinking. The future teacher's responses can be categorized as falling into a few select themes:
- The importance of pre-service teachers knowing the phenomena (in this case, one of many processes in the water cycle) in question;
- Being able to anticipate the nature of the conceptions students may harbor prior to instruction and form as a result of instruction;
- Having the ability to "think on one's feet" to be able to respond to students' thinking;
- Being able to generate questions, from lower level questions designed to review a lesson in which students participated, to higher order questions designed to promote students' analysis and meaning-making of the phenomena studied.

Case 2: Eliciting Students' Thinking about Long Division Algorithm in Elementary Mathematics Methods Course

The elementary mathematics methods course is currently pre-requisite to take two semester-long student teaching assignments, so PSTs had limited opportunities with eliciting, interpreting, and responding to students' mathematical thinking. Given this context, the mathematics methods course provided opportunities for PSTs to analyze the artifacts of teaching practices (e.g., video of mathematics lessons; student work samples) and to rehearse number talks in front of their peers who played a role of students at the beginning of the semester. This project is a pilot study to examine the effect of digital simulations with avatars, compared to non-digital simulations with their peers as hypothetical students. The goal of this simulation is to provide opportunities for PSTs to approximate the core tasks of teaching in a safe environment by using the power of pausing, giving immediate feedback, having multiple

opportunities to rethink and re-enter to instructional interactions, providing peer-coaching, and finally making a better instructional decision. The simulation used the pre-developed scenarios by Mursion for one of high-leverage teaching practices (i.e., eliciting student thinking) related to a long division algorithm.

During the simulation, each team (one teacher and one peer-coach) has 10 minutes to elicit student thinking about a long division algorithm. Overall, the first PST in the simulation started with generic questions (e.g., What do you think about Lia's work sample?) but the last PST in simulation asked more content-specific questions using turn-and-talk and revoicing talk moves (e.g., So, you are saying that Lia was most like Jasmine? How would you say that Lia's work is similar to those students?). The number of PST-initiated "pause" ranged two to four times but they mainly paused the session when they had difficulty in handling students' non-mathematical comments or searching for accurate mathematical vocabulary to use. The number of avatars selected, the duration of interaction with one avatar's idea, and the pattern of questions also varied by PSTs. Each PST had his or her own pattern of asking questions and repeated similar questions to different avatars. For example, PST 1 asked a series of questions about the method (e.g., What do you think? What kind of methods do you think that Lia did in her math problem?), PST 2 focused on operation (e.g., Did she add or subtract?), and PST 6 focused on similar strategies between students.

In the reflection paper, the PSTs mentioned that they felt intimidating and overwhelmed to interact with avatars in front of their classmates and professor. However, all PSTs highlighted the benefits of simulations to learn the core teaching practices as follows:

- The simulation is very similar to a real classroom and this simulation helped me realize that more specific questions elicit better answers.
- The benefits of doing this simulation are getting a chance to practice in a classroom setting with students and being able to get support and feedback from my classmates. I learned that it is very important to be prepared and ask open-ended questions to get students thinking.
- You get a sense of what scenarios might occur in a real classroom setting. The "pause" setting is great because it gives you the chance to stop, refresh, and come up with better questions.
- The simulation helps for us to get used to real student responses. Kids are much different than peer teaching to adults.
- I learned how to ask more specific probing questions, rather than broad questions. They responded a lot better to specific questions.

Future Directions

The integration of digital simulation into a methods course is relatively new but the PSTs commented that simulation is a great way to learn about teaching practices. Our initial analysis of digital simulations suggests a number of future directions of fruitful research.

1. Does one class session with the simulator have a significant impact on teaching practice as applied in an actual classroom? Are additional sessions needed to significantly impact PSTs' ability to elicit students' thinking on alternative scientific concepts and alternative mathematics algorithm? If so, how many sessions might be necessary to impact their abilities in this area? When do we need to offer simulations for PSTs? Does the simulation provide a sufficient foundation on which to build strategies in eliciting students' thinking?

2. What instruction on student thinking, questioning strategies, and different levels of questions would prepare future teachers to maximize the simulation experience for eventual transport of skills to an actual classroom? What activities, instructional routines, or pedagogical content knowledge support the successful implementation of digital simulation?

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Assessing Teaching Practice: Eliciting and Interpreting Students' Mathematical Thinking

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Keywords: mathematics education, teacher preparation, assessment, live simulation, approximation

Project Overview

The Assessing Teaching Practice (@Practice) Project develops and studies teaching simulations to assess preservice elementary teachers' (PSTs') engagement in high-leverage teaching practices and use of mathematical knowledge for teaching. We view simulations as approximations of practice that place authentic, practice-based demands on teachers, while purposefully suspending or standardizing some elements of the situation that allow for a focus on particular teaching practices and the use of mathematical knowledge. Within a simulation, PSTs engage with a teacher educator whose knowledge, words, and actions are standardized to be in line with a carefully crafted profile of a student's mathematical thinking (hereafter written as student). Our assessments are used for formative purposes by our teacher education program, instructors, and PSTs, in concert with information from the field.

We design simulations to catalyze the need for PSTs to engage in high-leverage teaching practices and use mathematical knowledge that is crucial to teaching. We use the term high-leverage to indicate practices that are routinely needed to teach mathematics, crucial for supporting robust learning opportunities for all students, and learnable in teacher education contexts (Ball, Sleep, Boerst, and Bass, 2009). We focus on the high-leverage teaching practices of eliciting and interpreting students' mathematical thinking because of the essential need for teachers to learn about and make connections with what students think (insights secured through proficient "eliciting") and derive meaning from students' words and actions in ways that are grounded in evidence, unbiased, and generative as the basis for subsequent action (meanings established through proficient "interpreting"). In terms of mathematics, we focus on mathematical knowledge for teaching (MKT). We use the definition presented by Ball, Thames, and Phelps (2008) that distinguishes the specialized set of knowledge needed by teachers to support students' mathematics learning and the way in which teachers need to hold that knowledge such that it is useful in the tasks that teachers need to accomplish before, during, and after/between instructional interactions with students. Specifically, we design simulations focused on number and operation, topics that are core to elementary teaching.

Our simulation assessments consist of three parts. In the first part of the assessment, PSTs are provided with student work on a problem and a short period of time to prepare for an interaction with the student. In the second part, PSTs have five minutes to interact with the student, eliciting and probing the student's thinking to understand the steps she took and her

understanding of the process and key mathematical ideas involved. To ensure standardization, the student is trained to follow the highly specified rules for reasoning and responding, including responses to questions that are commonly asked by PSTs. In the third part, PSTs respond verbally to a set of questions that are designed to elicit their interpretations of the student's process and understanding. Both the interaction with the student and the responses to the follow-up questions are video recorded. The assessment takes approximately 25 minutes and is scored in the moment based on criteria for proficient performance, including mathematically and pedagogically key aspects.

Theory of Action

Teaching is a practice. It is something that teachers do, not merely something they know. Therefore, to prepare future teachers, we must engage PSTs in doing the work of teaching. With increasing emphasis on practice-based teacher education, there is a correlated need to develop assessments that provide information about PSTs' abilities to engage in high-leverage teaching practices and use mathematical knowledge in their teaching. Simulations provide a way to assess enacted skill and knowledge, while standardizing content and contextual factors. They provide an important complement to assessments of teaching that happen in, and are influenced by, situationally varying school contexts. Further, since simulations do not involve PSTs directly with students, they also are capable of securing information of PSTs very early in the teacher preparation process, even at its very outset. Teaching/learning interactions at every level, including between teacher educators and PSTs, benefit from information that can guide subsequent learning opportunities, thus simulations provide a very important tool for teacher educators to learn about the knowledge and skills that PSTs bring to initial preparation.

Our simulation assessments (Shaughnessy & Boerst, 2018b) are grounded in decompositions of eliciting and interpreting students' mathematical thinking. PSTs engaging in the simulations:

- Elicit and probe a student's computational process and understanding; take up the student's ideas in questions; show their respect for the student and their thinking; and use mathematical language and representations.
- Interpret student thinking by making qualified claims about student thinking; use evidence to generate and test claims; match the scope and nature of the claim to the amount and type of information available; actively work to prevent bias or distortion; and develop and/or use appropriate criteria to focus or inform judgments.

Unlike an actual setting of teaching and learning, the simulation does not require PSTs to take steps to orient the student to the situation, to earn a student's trust prior to engaging in conversations about the student's thinking, have a graceful way of exiting the conversation, or convert insights into the student's thinking into pedagogical action. Those actions set the context for, or follow up on, engagement in the high-leverage practices of eliciting and interpreting and are therefore possible to suspend for the purposes of the assessment. Of course, the most substantial distinction between the simulation and an actual teaching

situation is that the PST is not interacting with a child. Each student profile is painstakingly designed using research, curriculum, and teaching experience to represent an actual numerical approach and understanding of an elementary aged child. The assessment is not meant to replace work with actual students, but rather to provide a context for assessing teaching practice and teaching knowledge that can fairly and repeatedly be used with groups of PSTs while avoiding complexities and pitfalls in enactment and judgement that in our experience were common in other approaches (e.g. field interviews of students).

We initially developed our assessment simulations for use within our own teacher education program. Through a restructuring of our teacher education program to focus on a set of high-leverage practices, there are windows of time built into the beginning, midpoint, and end of our program for administering assessments to provide information to the program, instructors and PSTs. In addition to using simulation assessments during these windows, we have also used them in "office hour" and "follow up to a PST's individual learning plan" type contexts. Each of these contexts requires the training of proctors (teacher educators, field instructors, graduate students), scheduling administration, and organizing scoring appropriate to our current use model within a relatively small teacher education program (n< 80).

Our assessments are not specifically used to promote learning; however, we routinely see examples of PSTs' learning. Videos of simulations, post simulation interviews, and later informal conversations with PSTs (sometimes surprisingly long after) reveal PSTs "ah ha" moments where they realize important things about the teaching practices (needing to ask questions about the student's understanding, information they gathered that was not very useful, evidence that they wish they had, posing a follow up problem to learn more) or the mathematics involved in the simulation (that the student's process would generalize, that their own investment in a different process impacted their ability to hear a student's mathematical reasoning). This is not a surprise as the simulation context that enables assessment of engagement in eliciting and interpreting and the use of mathematical knowledge is also a context where PSTs can learn through experience. We are currently enhancing the simulation design to more consistently provide learning opportunities.

Learnings

Findings about Teachers Candidates' Skills with Eliciting and Interpreting Student Thinking
We have used simulations to study PSTs' skills with eliciting and interpreting student thinking in mathematical contexts. One study focused on performance upon entry to our teacher education program, revealed that PSTs are likely to ask about a student's process for solving a mathematics problem (elicitations about specific aspects of processes are in the 80-90% range); however, PSTs are less likely to ask about the student's understanding of the core mathematical ideas (Shaughnessy & Boerst, 2018a). Only 68% of our PSTs asked the student about their understanding of the process. About half of PSTs stated a step in the student's process or an

understanding of the student without asking questions to learn about the student's thinking. Further, the same PSTs rarely posed follow-up problems at the beginning of the program (15%) to confirm the student's process or understanding. These findings suggest moves that need to be learned or unlearned, as well as moves can be built upon.

We have analyzed capabilities with interpreting student thinking at the beginning of the program (Boerst, Shaughnessy, & Ball, 2017) and found that the assessment reveals both resources that PSTs are bringing (e.g., explaining the process used by a student) and areas upon which teacher education needs to focus (e.g., making evidence-based interpretations of student understanding). In a related study, we compared the interpreting practices of a group of PSTs using simulation assessments at the point of entry into the program and at the program midpoint (Shaughnessy, Boerst, & DeFino, 2018). Focusing specifically on interpretations of student understanding, we explored two different contexts. In one context, the understanding is one that we hypothesized would "provoke questions" for PSTs. That is, the understanding is one that would be a focus of interactions with the student. In this context, we found that, PSTs increased in describing the student's understanding accurately with evidence (from 63% at baseline to 80% at the program midpoint). In a contrasting context, in which we believed that PSTs would be like to assume the student's understanding and not ask, we found that there was a marked increase in recognizing the need for more information before anticipating (from 26% to 50%). These findings suggest that PSTs got better at making evidence-based interpretations, including recognizing when they did not have sufficient information to make a claim about the student's understanding.

Findings about Assessment Design

We analyzed the predictability of questions posed by PSTs, coding every question posed in video records of 36 simulations (Shaughnessy, Farmer, DeFino, & Boerst, 2019). We found that for 95% of the questions posed, there was guidance available in the student profile for responding. These results suggest that the student profile is sufficient for providing guidance to the simulated student for responding in standardized ways. Fifty-six percent of the questions posed corresponded with questions we had anticipated when designing the student role protocol. The remaining questions posed varied from those predicted. However, the developed profiles provided support for responding to almost all of unscripted questions. The student could draw on other guidance provided in the role protocol, such as information provided about the student's understanding of relevant mathematical concepts and general demeanor. These findings suggest that student profile provided support for the student to respond to questions, but that is necessary to have a live student.

Findings about Assessment Quality

To be worth the time investment, simulation assessments must be valid measures and contribute new and important information about PSTs' skills. To investigate whether the

simulation could do both of these things, we examined the concurrent validity of the assessment. We had a group of PSTs (N=48) complete a simulation assessment and an interview of a child in their field placement, about mathematics content that was similar to the content of the simulation. Using the video and work products generated, we explored how well performance on one assessment matched the other with respect to the key components of the eliciting practice. Analyses of the cases, as well as more in-depth studies of particular cases (see Shaughnessy, Boerst, & Farmer, 2018), demonstrate that the simulation is able to capture the same eliciting practices, and corresponding qualities of performance as the field embedded assessment with respect to many elements of eliciting. In cases where the performances in the two situations were not aligned, our analyses surfaced differences in how much information students in the field volunteered without prompting.

Simulation assessments depend on the ability of simulated students to consistently "stay in character" so that each PST will interact with essentially "the same" student. We have developed detailed training materials for each simulation assessment. In a recent study we examined 36 performances of four trained teacher educators, external to our institution, in the role of the student. We found that across 36 performances, in a large majority (85%) of exchanges between trained teacher educators (as simulated students) and PSTs, the teacher educators responded in ways that adhere to the content and rationale of the student role protocol. This suggests that it is possible to train teacher educators to implement simulations with fidelity with reasonable investments of time and effort.

Future Directions

In one strand of work, we seek to understand how the simulations can be used in different contexts to provide formative information to teacher educators, PSTs, and teacher education programs more broadly. We aim to (a) understand how simulation assessments can be implemented within teacher education contexts with different populations, as well as resources, needs, and priorities; (b) understand the nature of (re)design work needed for simulations to be manageable and valid in individual sites that differ in emphases of work within teacher preparation and institutional capacity to carry out the administration and scoring of the assessment; and (c) create tools and routines that support the translation of performance data into information that is usable by teacher educators. In a second strand of work, we are redesigning the simulations to be robust opportunities for learning about mathematics as well as teaching practice. Our current work focuses on identifying and studying features that are most powerful for supporting PSTs' learning of mathematics.

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Acknowledgments

Considerations in Designing Math and Science Simulations with a Human in the Loop

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Keywords: Digital simulation, live simulation, teacher preparation

Project Overview

The TeachLivE / Mursion virtual classrooms are simulated classroom environments designed to facilitate interactive teaching practice where teachers can present lessons, respond to student questions, evaluate student thinking, facilitate discussions, and respond to classroom management challenges. The virtual classrooms can be viewed via a traditional screen projection system or in a head-mounted virtual display. These interactions can be recorded for after-action review, scoring, or self-reflection. These TeachLivE / Mursion environments contain one to six avatars that are controlled by a human, called an interactor or simulation specialist respectively. Avatars in the environments can range in age from Kindergarten to adult.

Over the past decade, pre-service and in-service teachers have used these systems to practice mathematics and science lessons from Kindergarten through University level. The most common goal selected for these simulation sessions, beyond practicing classroom management strategies, is to analyze student thinking, identify misconceptions, and evaluate student levels of comprehension. Thus, this paper explores simulation design considerations with that goal in mind.

Theory of Action

Simulated Features of Teaching

Discerning individual student understanding and communicating in a way to build her or his skill is a nuanced, multi-faceted activity. Facilitating discussion, encouraging higher order thinking, shared inquiry, and conceptual analysis are considered best practices in education; but there are few opportunities to practice this outside of an actual classroom. The simulated classroom provides opportunities to practice these discrete skills. Having a human in the loop allows the interaction between the participant and the characters in the virtual environment to feel authentic. The student avatars can respond in real time and represent diverse perspectives and conceptions (or misconceptions) of the topic being discussed.

In the TeachLivE / Mursion simulation platforms, teachers can use visual materials, manipulatives, white boards, and other presentation materials in front of the virtual classroom. These materials are seen by the interactor / sim specialist via a webcam or a shared whiteboard application so both teachers and the interactor / sim specialist can work through problems together. In this manner, direct content instruction and diagnosis of errors via student work are approximated. Additionally, teachers may verbalize any questions since the interactor / sim specialist can hear the teacher in real time and construct an appropriate response based on

student academic and personality profiles. This provides practice eliciting student thinking as well as facilitating classroom discussions and peer-to-peer interaction.

The Use Model

While the use model for the TeachLivE / Mursion simulation platforms may vary in specific contexts, the simulation experience is a part of a larger instructional cycle. Generally, faculty select one to three specific, measurable teaching practices that they wish to target for the simulation and share these goals with the learner. Depending on the level of experience of the learner, instruction on how to apply these practices often precedes the simulation experience. During the session the learner receives behavioral feedback from the student avatars that has been calibrated to the learner's level of mastery. During or after the session learners also receive targeted feedback from a professional coach. Learners are asked to reflect on their teaching choices as well. Ideally, multiple points of data should be collected from the learner through additional simulation experiences or through observation in a real classroom. This data can be analyzed to measure whether performance improves over time and if it transfers to a real classroom environment and student outcomes.

To address issues of consistency in sessions, design considerations include: the level of standardization of response, the defined profiles or patterns of thinking, the specific content, and potential progression of thought or "learning." In the national study funded by the Bill and Melinda Gates Foundation (Dieker, Hughes, & Hynes, 2016) the 5 avatars each had an algebra work sample that aligned with each student's academic and personality profile. The error patterns were selected with guidance from math expert Ann Shannon. The written work and portrayal of understanding was developed by the lead interactors / sim specialists. Currently, ETS and Mursion are collaborating on an NSF funded study (Mikeska & Howell, 2016) on building classroom discussion skills in pre-service teachers. During the development of the materials, science content experts and veteran teachers develop content lessons and profiles, then work with lead interactors / sim specialists to create performance protocols of content keys that would unlock student misunderstandings. These partnerships of expertise align to maximize the impact of the simulation for the learners.

Expected Learning

The expectation is that teachers will improve their teaching practices with feedback on their performance and guidance from expert coaches. The hope is that through interacting with avatars in a safe virtual space, teachers will learn to listen and focus on the students and interpret what they are saying or the work they are doing or have done, and make connections with the content or lesson objectives. The opportunity to connect student ideas and elicit student thinking and encourage deeper analysis is supported by the immediate response of the class. Simulation is also an opportunity to practice teacher presence and presenting content in an engaging way. While there is performance pressure, in most scenarios the only consequence

of failing is the opportunity to reflect and try a different approach. In order to determine if this learning has occurred, data on targeted teaching practices must be gathered both before teachers engage in the simulation and afterwards, preferably in a real classroom context.

Learnings

Melinda Gates Foundation suggest that simulation sessions affect teacher behavior. The recent pilot of the Educational Testing Services (ETS), National Observational Teaching Exam (NOTE), supported by Mursion, provided evidence of interactor / sim specialist reliability (Gilespie et al., 2018). For the purposes of this paper, we are focusing on the informal learning trends gleaned from over a decade of small studies and direct interaction with learners that we have found improves simulation training outcomes in math and science.

Learner Analysis & Objectives

- Prior to designing objectives and materials for the simulation experience, it is important to evaluate the current skill level of teachers that will be using the system and plan appropriate challenges. When the level of difficulty or intensity will vary based on teacher skill, providing interactors / sim specialists with clear performance guidelines and decision points for escalation is critical to maintain standardized experiences that do not sacrifice responsiveness to individual learners.
- Objectives need to be clear, defined, and measurable; and should be shared with both learners and with the interactor / sim specialists. We've found that learner outcomes improve when the objective is clear to the learner. Additionally, we've found that interactor / sim specialist performance choices are more aligned with session objectives when those objectives are known.

Materials Development

- In the domain of mathematics lessons especially, we found that research-based student work samples were critical to both provide a starting point for teachers to elicit student thinking and for standardizing student misconceptions portrayed by the interactor / sim specialists.
- In the domain of science lessons, focusing on a specific content area or experiment allows for a more authentic interaction rather than introducing a broad, general concept.
- Defining a scope of student understanding for content, including familiar and unfamiliar concepts and vocabulary, aids standardization and helps interactors/ sim specialists respond in a way that is research based and developmentally appropriate.
- Creating a one-page synthesis of reference materials that can be used during the interaction can allow the interactor/sim specialist to focus on key elements of the interaction rather than memorizing or flipping through materials and potentially missing a significant teacher action.

Interactor / Sim Specialist Procedures

- Particularly for math and science applications, training and rehearsal time are essential. Practice sessions should be run with members of the target learner population with subject matter experts providing feedback on interactor / sim specialist performance and choices. Often these practice sessions identify areas in the materials or objectives that require further definition or clarification to either learners or interactors / sim specialists.
- Standardization guidelines that include expected class behavior or actions that are applied across multiple scenarios creates consistency of performance with different interactors / sim specialists.

Facilitation Procedures

- Prior to interacting with the system, facilitators should share any applicable system limitations with learners. For example, one system limitation is that the student avatars cannot engage in choral response. If not informed of system limitations, learners may waste time trying to engage the whole class in a choral response that cannot be achieved. If learners are not told of system limitations, it can create a negative experience for learners if they have planned to use teaching practices that are not supported.
- Facilitators should address the avatars as if addressing a real classroom. We've found that having the facilitator model interaction with the simulated environment as if it were a real classroom helps learners step into the environment and reduces potential anxiety as the learner becomes immersed in the experience.

Reflection Process

- As a part of the Gates study, when we ran simulation sessions, our expert coaches collected observational data by hand and shared it with teachers. We found that many teachers resisted the data frequency counts and questioned the accuracy of the coach in observing defined behaviors. In later iterations, we found that allowing the coach to input observational data into the software directly and then having the collected data appear on screen as a graph increased teacher acceptance of the data. Our theory is that teachers may have felt that the data appearing on screen was more objective than data shared verbally by coaches even though the data was gathered in the same manner and only presented in different ways.
- With corporate learners, we are piloting the use of a Host Avatar to provide opportunity for reflective feedback. This provides an environment of anonymity and safety for the learner. The process can be recorded for additional reflection on the experience and indicate future goals for the next simulated or real interaction.

Future Directions

One area in need of additional research is measuring the effect, if any, simulated teaching experiences have in changing student outcomes. While current research suggests some effect on teacher behaviors, no information has been gathered that suggests an effect on student

outcomes, which would be the ultimate goal. Additionally, while significant effort has been placed into ways of standardizing interactor / sim specialist performance for consistency, research has not yet explored the facets of interactor / sim specialist performance that may affect training effectiveness and learner perceptions of authenticity of practice. Finally, while some research has been conducted on the simulated environment in terms of how it affects sense of presence, very little work has been done to learn how specific choices in avatar character design may also affect training effectiveness and transfer of practice into authentic teaching environments.

Another area of research interest is using mixed reality simulation directly with K-12 students to improve content mastery, classroom discussion skills and social emotional learning. The initial findings of use with students with special needs to build social skills and peer tutoring applications have been promising, but the fields of math and science have been minimally explored in this use case.

As the fields of immersive learning, augmented and virtual reality and AI continue to advance, we can incorporate innovations that would benefit the learning objectives of the simulations. For instance, a study being done in collecting data on student engagement using an algorithm reading facial expressions could be combined with the live interactive simulation to provide both experiential learning and post session analytics. Additionally, system development that allows more actions and situations to be realized in the virtual classroom would extend the application potential. For example, if virtual students can manipulate 3-D objects in a science lab environment, there could be embedded scenarios of experiments set up correctly or incorrectly, allowing the learner to facilitate the activity and discussion.

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Design Principles and Process of Designing Mursion Scenarios with Teaching Candidates

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Keywords: teacher preparation, rehearsals, live simulation, digital simulation, VR

Project Overview

The Woodrow Wilson Academy of Teaching and Learning (WW Academy) is an innovative competency-based teacher education program in collaboration with MIT. The WW Academy curriculum utilizes many digital and non-digital simulations, which we define as learning experiences where teachers rehearse for important moves they make when interacting with students and adults, and then reflecting on those rehearsals. Some of our simulations require teacher candidates to approximate the full complexity of teaching by coordinating multiple competencies. For example, to facilitate a discussion, teacher candidates (TCs) coordinate the competencies "Leading Collaborative Learning" and "Adapting to Performance Data." Other simulations are narrower in scope in the sense that they help teachers develop dimensions of a competency (i.e., learning objectives). For example, there is a simulation targeting the learning objective "Develop standards of conduct that are designed with, understandable by and available to students," which is part of the "Building a Community of Trust" competency. Last year the faculty and staff designed the first version of the curriculum in collaboration with TCs. Currently we are implementing the curriculum with twenty TCs and collecting feedback to inform iteration.

The simulations in our curriculum include those designed by us, our collaborators at MIT's Teaching Systems Lab[3], and Mursion, a developer and provider of digital simulations with student and adult avatars controlled by a remote operator. A Mursion simulation design consists of four parts: learning objectives; a scenario, a problem that the teaching candidates need to solve; "hits and misses," examples of effective and ineffective responses by the TC and how the avatars should respond; and debrief questions, prompts for feedback and discussion following the simulation. The Mursion simulations that we have designed are aimed at developing TCs' abilities to establish classroom norms, explain how to support a student with an IEP, facilitate a family conference, and uncover and mitigate biases in their practice. Below we summarize the design principles and process we use to develop Mursion simulations, which may be useful to other teacher educators who are designing simulations, more broadly. We illustrate the design principles and process using a recent example—a simulation that requires TCs to respond to student who has accused them of racist behavior.

Theory of Action

Our design process reflects the perspective of Schuler and Namioka (1993), who argue that high-quality products require not only testing by users (e.g., TCs), but their **active involvement in design** (Table 1, Design Principle 1). Following this idea, the real problems that TCs encounter (e.g., in their student teaching) are often the inspiration for Mursion scenarios. Faculty may also begin by identifying a need in our curriculum - a need for a learning experience or assessment of a competency (Figure 1, Stage 1). Whatever the inspiration, we ensure that the simulation is **aligned** with the WW Academy competencies and that it is **realistic** (Design Principles 2 and 3). We also view Mursion as a **unique opportunity** to practice solving problems that teacher candidates do not often get to practice, sometimes because the authentic situation (i.e., the non-simulated environment) is **high-stakes** (Design Principles 4 and 5). These two principles, unique opportunity and high-stakes, are used to filter and select which problem to feature in the scenario (Figure 1, Stage 2). Due to the affordances and constraints of the Mursion platform (described in Learnings section), some problems play out in ways that provide **opportunities for TCs to practice effective decisions** (Design Principle 6) that align with our vision, so we choose to develop those scenarios that are amenable to Mursion's technological capabilities.

Figure 1: Mursion Design Process
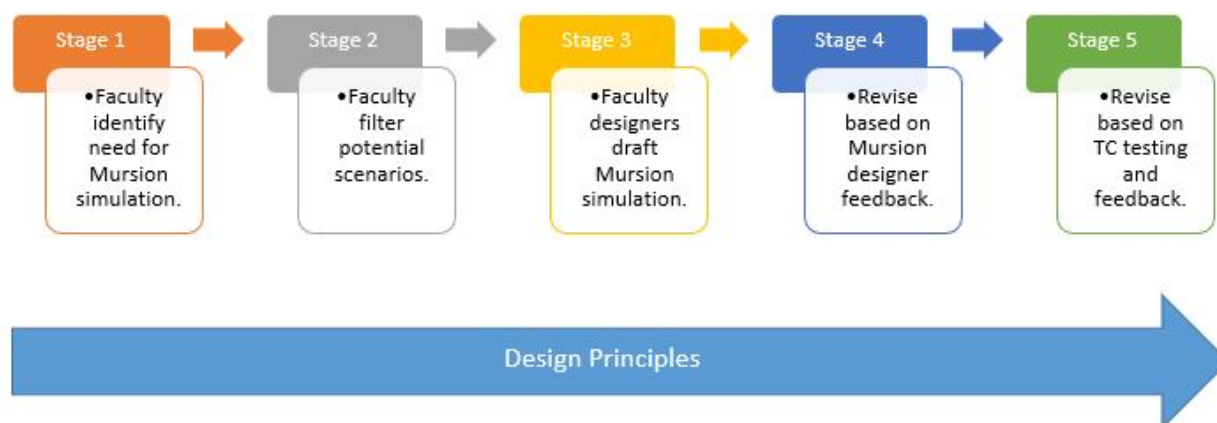
Design Principles for Mursion

1. **Actively involve TCs in design**. Simulations are better when the users (TCs) have a substantial voice in the design. The problems TCs encounter may initiate the design of simulations. TCs test/try the simulation, provide feedback, and suggest revisions.
2. **Aligned**. Engaging in the Mursion simulation results in progress toward the targeted learning objectives in the WW Academy competencies.
3. **Realistic**. The scenario targets a real problem that teachers have encountered and interacting with the avatars feels similar to interacting with real people.
4. **Unique opportunity**. The problem is one that TCs do not often get to practice with in "real life" (e.g., participating in an IEP meeting).
5. **Authentic is high-stakes, simulation is low-stakes**. It would be important to address the problem effectively in the authentic (i.e., not the simulated environment) because not

doing so would have significant negative impacts on the relationships with the students/adults. While the anticipation of the simulation may be provocative, engaging in the simulation feels safe for TCs because they can make mistakes without the negative consequences.

6. **Opportunity to practice making effective decisions**. The affordances of the Mursion environment and avatars are leveraged so TCs have the opportunity for practicing our vision of effective practice, as articulated in the WW Academy competencies. Avoid designing scenarios where Mursion constraints limit enactment of our vision. Also, provide a trailer, not a script: give a glimpse of the problem so it sparks interest in solving it, but don't provide so much information that TCs have little need for engagement.

7. **Deepen understanding through the debrief**. Deepen TCs' understanding of the problem featured in the scenario, ways of responding, and themselves. The reflection prompts should help TCs use observations to identify successes and areas of improvement and help observers provide specific and actionable feedback. The prompts should also help TCs unpack the problem featured in the simulation and their emotional experience.

Beyond the selection of the scenarios, we utilize the Design Principles throughout the design process. For example, when faculty designers draft the "hits and misses" (in Stage 3), they consult experts (e.g., experienced teachers, literature) to articulate examples of effective practice and ensure those examples are aligned with the WW Academy competencies. In drafting a high-stakes scenario, the faculty designers provide information so that TCs can prepare and have a low-stakes simulation experience. To ensure that TCs can to practice decisions that reflect our vision of effective teaching, we provide them with enough information for them to prepare and spark their interest, but not so much as to preclude decision-making (i.e., provide a trailer, not a script). Another part of Stage 3 is drafting the debrief prompts with the intention of deepening TCs' understanding of the problem featured in the scenario, ways of responding, and their emotional experience (Design Principle 7).

In Stage 4, a Mursion designer provides feedback on the scenario and the faculty designer collaborates with that person to revise. In Stage 5, the Mursion designer controls the avatars as a TC tests (i.e., engages in) the simulation. The faculty designer observes the simulation to compare the TC's comments and actions to the learning objectives. After the testing, the TC provides feedback by sharing how realistic the simulation felt and suggesting revisions. The Mursion and faculty designers revise the simulation based on the feedback, and the testing and feedback process is repeated at least once.

Learnings

In this section, we illustrate how we have used the design principles and process described above to design a Mursion simulation in which the TC is accused of enacting racial bias. The

provocation/inspiration for this scenario (Stage 1) came from one of our TCs, who in her student teaching, observed her mentor teacher take one student's phone but not another student's. The student whose phone was taken said, "That's racist," and the teacher responded sarcastically. The TC then came to the WW Academy distressed about the incident and spoke with several faculty members about it.

When four faculty designers met to filter potential scenarios (Stage 2), this problem came to mind, in light of our design principles (e.g., realistic, unique opportunity, and high stakes in real-life, low-stakes in practice). We also recognized that simulation would be useful for developing two learning objectives in our competencies, and that we needed to design the simulation so that it was aligned with these learning objectives. These learning objectives were: "Identify the influence of bias in their own practice." (Competency: Teaching for Justice) and "Relate to their students in ways that respect their independence, agency, and dignity" (Competency: Relating to Students). Furthermore, we anticipated that there would be opportunities for TCs to practice making effective decisions- in our view, expressing empathy for the students' feelings and attempting to better understand what the student interpreted as racist. The Mursion platform would enable TCs to respond in these ways because it offers an environment where TCs interact with five middle school students and another environment where TCs can interact with a student 1-1. In other words, the TC would be able to, for example, ask the student to write a note about what felt racist or to meet 1-1 after class to further discuss the matter.[4]

After deciding on the scenario, faculty designers drafted a scenario (Stage 3), further utilizing the principle of providing opportunities to practice making effective moves. They offered a trailer for how the simulation might "play out," without giving so much information that precludes improvisation:

> You've only met with your advisory group twice in the year that recently had some racial tension in the school. Today you are continuing to build community by playing the game "two truths and a lie." The goal of this game is for students to fool each other into thinking that a false statement about themselves is true. Students write down three facts about themselves, one of which is false, and then guess which one is false. Be ready to redirect students' behaviors in order to establish a classroom culture where students listen and respond respectfully to each other.

The scenario foreshadows a problem related to race and provides enough information for TCs to anticipate what might happen and prepare different ways of responding to situation. We

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[4] In contrast, we have learned that the Mursion setting with five middle-school students limits the opportunities for our TCs to practice redirecting behavior (i.e., classroom management) in ways that reflect our vision. We would like our TCs to interact 1-1 with students versus respond to all behaviors publicly, and that way of responding is not afforded by the platform.

have noticed that TCs often practice what they will say and do in advance of the simulation, which we view as evidence of provocation and providing information that helps TCs prepare. Part of Stage 3 includes specifying the ways the avatars might respond during the simulation. In this case, the designers specified that an avatar will demonstrate a disruptive behavior until the TC redirects them, and in response, the avatar says, "That's racist." In order to further "set the stage" for effective practice, faculty will remind TCs of the affordances and constraints of Mursion, including the ability to have a 1-1 conversation after class. If the TC does not initiate that conversation, the Mursion actor who controls the avatar will ask the TC to talk after class, which nudges TCs away from a default of addressing problems in front of other students and toward a practice of deepening their understanding of the student's experience. In the debrief, we will ask TCs to reflect on the emotions they experienced during the simulation and factors that may have contributed to those emotions, with the goal of developing mastery of the objective "Identify the influence of bias in their own practice."

By the time of the Simulations in Teacher Education Conference, we will have progressed through design Stages 4 and 5 and have video available to show how TCs contribute to testing, feedback, and revision. A TC will also attend the conference to provide a first-hand account of the experience engaging in the process.

Future Directions

We are eager to compare our design principles and process to those used by other teacher educators and designers. We are curious about the affordances and constraints of applying design principles and processes to different types of simulations and in different contexts. As another future direction, we are experimenting with the use of Mursion as an opportunity for TCs to respond to scenarios in in different ways (e.g., pushy, deferential, reactive, compassionate). This last idea raises the question, "How might teachers use simulations to experiment with ways of responding that move them out of their comfort zones and open up alternative strategies for addressing student behaviors or for responding to students?"

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Does the Teach Live Simulation System Improve Pre-Service Teachers' Self-Efficacy?

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Keywords: Science education, mathematics education, teacher preparation, digital simulation

Project Overview

My interest in digital simulation stems from my military background. While working at the United States Military Academy (West Point) last academic year, I embarked in an investigation of military simulation. The West Point Simulator Center mission is to educate, train, and inspire the Corps of Cadets through design, development and application of full spectrum simulation training programs (usma.edu, 2017). The Department uses three systems, the Engagement Skills Trainer 2, Virtual Battle Space 3 (VBS3) and Cave Automatic Virtual Environment (CAVE). "The realism associated with Virtual Reality training greatly accelerates learning and skill acquisition (Koźlak, Kurzeja, and Nawrat, p. 328, 2013)." Each one of these simulators are used for a variety of training, but like all virtual reality, meant to enhance cadet field training experience.

This work served as a catalyst for matriculating me through my doctoral coursework at Lamar University. This past fall I was awarded an academic fellowship which is allowing me to receive a stipend while continuing my research on digital simulation. Due to the fellowship's requirement of all work being in the field of teacher education, I have shifted my focus away from military simulation and have teamed with Dr. Levin from the University of Maryland and his research with the Mursion[5] system. I will present qualitative data collected by Dr. Levin from his research with pre-service teachers (PST) and their views of the Mursion system. The data will focus on the PSTs increased feeling of greater confidence or self-efficacy in leading classroom discussion.

- Simulation: "For simulated environments to be effective, they must provide a sense of "real presence," much like the difference between a pre-service teacher reading about behavior management to experiencing real students and real classrooms (Dieker, Rodriguez, Lignugaris/Kraft, Hynes and Hughes, 2013, p. 23)." The Mursion simulation is real in that each PST has the opportunity to lead a discussion about a scientific phenomenon to the avatars in the Mursion system. This is an opportunity to approximate the experience they could actually experience when leading a discussion with children later in their student teaching experience.
- Teacher involvement: The participants in the simulations are PSTs enrolled in a middle school science and math undergraduate teacher preparation program at the University of Maryland.

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[5] Licensed by Mursion Inc. (www.mursion.com)

- How are they involved: The PSTs lead avatars in a 10-minute discussion about a science phenomenon or a math task as if they are in a real classroom. Following their class, they receive feedback from the professor Dr. Levin, and write reflective papers on their experience. The papers are designed to answer three specific questions related to their interaction with the avatars: (1) what they noticed in the ideas and reasoning brought up by the avatars, (2) how they responded to the avatars' ideas, and (3) how it felt to lead the discussion.
- The hope is PSTs will feel an increased level of confidence in leading classroom instruction through practice with the Mursion system, which they can then apply during their student teaching experience.

Theory of Action

Teacher self-efficacy (TSE) is the feeling of the teacher or pre-service teacher to achieve specific goals in leading students in a classroom (Ma & Cavanaugh, 2018). Through approximation of practice in simulated science and math-based discussions, PSTs will potentially increase their feeling of TSE.

This research included:

- Avatar approximation in a virtual classroom with five diverse students with different voices, mannerisms, and learning profiles1. Avatars provide realistic interaction with PSTs through human drivers. Avatars provide realistic answers to questions, react to body movement and speech of PSTs as well as ask their own questions to test PSTs.
- Expectation that pre-service teachers will increase their feeling of confidence in leading classroom instruction through practice with the Mursion system, which they can then apply during their student teaching experience. We will know if it has occurred through their reflective papers following the Mursion simulation sessions. Analysis will be conducted to identify data in their papers that suggests the PSTs felt greater confidence in leading classroom discussion following the Mursion sessions.

Learnings

The final data was collected in early December 2018, as such the data will be analyzed over the winter break. The researcher is currently reviewing the past two years of data to identify common themes and to determine if there is a connection to or lack of connection to increased self-efficacy in teaching through the use of the Mursion simulation system. Once previous data is analyzed, the current year's data will be completed enabling the researcher to compare three years of data.

Future Directions

Early analysis leads the researcher to believe the Mursion system builds the self-efficacy of PSTs in relation to their feelings of ability and performance in leading a classroom. Many of their comments stated greater comfort, getting better through experience or practice. Student four stated, "After having done the avatars, I feel more comfortable leading science discussions." Student 18 stated, "Overall, leading the discussion seemed to get better with experience for myself and everyone else." Current placement of the simulation is at the end of first semester during the senior year of undergraduate pre-service teachers. This placement has been strategically placed so as to create a natural step from academics into simulation. There were two limitations to the data collected. First, the PSTs only teach two 10-minute classes for science and two for math. Second, there is only one paper to pull the data from once they have completed their Mursion sessions. When complete, if the data confirms that PSTs gained invaluable confidence through the use of the Mursion before student teaching, it would suggest that more teacher development programs should implement a form of simulation usage before the PSTs move to student teaching.

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Exploring Authenticity and Playfulness in Designing of Teacher Practice Spaces[6]

Justin Reich and Meredith Thompson, MIT
Keywords: teacher preparation, role play, approximation, digital simulation, non-digital simulation

Project Overview

Every great teacher knows that skill development requires practice (Ball & Forzani, 2009); ironically, teachers themselves have limited opportunities to practice important teaching moves in low-stakes settings. In a comparative study of teachers, social workers and therapists, Grossman and colleagues (2009) conclude that "prospective teachers have fewer opportunities to engage in approximations that focus on contingent, interactive practice than do novices in the other two [helping] professions." Currently, novice teachers primarily learn in two types of spaces: Socratic seminar rooms in teacher education programs (or lecture-heavy workshops for in-service professional development) and practicum classrooms. The former affords discussion and the latter affords immersion into the challenges of teaching, but a third space—a practice space—is needed that combines an authentic experience of teaching with carefully designed scaffolds that support the development of teachers' skills and identity. In our research, we design teacher practice spaces, inspired by games and simulations, that allow teachers to rehearse for and reflect upon important decisions in teacher.

We observe that most efforts at practice in teacher education aim to approximate as completely as possible the experience of classroom teaching. To borrow an analogy from sports, most of these simulations are like "scrimmages," that are close analogues to the complete game. We believe that interesting design spaces can be found by exploring what "drills" for teacher education might look like, where we engage teacher-learners in non-teaching activities that help them develop skills and dispositions that are useful for teaching. When training young violinists, music teachers often use bow games: silly songs where violin-learners sing and vigorously wave their bow with specific motions while maintaining the correct grip on the bow handle. Young soccer athletes play games such as keep-away to develop ball-handling skills. A violinist will never waive her bow maniacally above her head in a recital, and a soccer player will never play keep-away during a match, but these drills isolate particular skills for development that are then re-integrated—ideally with greater competency—into the complex assemblage of the whole activity. Our teacher practice spaces aim to introduce new kinds of drills into teacher education, and if these drills prove successful, then they could be placed alongside discussions of theory, holistic simulation, and field placements in the

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repertoire of teacher educators. Our work is driven by two overarching design questions: 1) what are the affordances and constraints offered by different dimensions of authenticity in the design of teacher practice spaces, and 2) what new design opportunities open up when relaxing constraints of authenticity?

Theory of Action

Within pedagogies of enactment, one dimension of authenticity that has been well theorized can be called *authenticity of complexity* (Kazemi, Franke, & Lampert, 2009). As Grossman and colleagues (2009) explain, one of the tensions with pedagogies of approximation is how much to approximate. Teaching requires deploying skills simultaneously in a complex assemblage—in a real classroom a teacher is simultaneously watching the clock, evaluating student attentiveness, drawing on knowledge about student relationships and competencies, and making decisions about pacing, behavior management, and student agency. Each of these teaching decisions is intimately entangled with the others, so a tension emerges between isolating skills out of the complex assemblage for practice (since the isolated skill is easier to address than the whole assemblage) and recognizing that none of these elements are actually isolated in real classrooms. Some of Mursion's virtual teaching scenarios attempt to embrace this full complexity, by having teachers teach lessons in front of a set of students with differing levels of understanding and classroom management issues. Dotger's scenarios elide some of these issues by focusing on very realistic scenarios from teaching that are less complex than classroom teaching, like talking to a single parent.

A parallel set of dimensions of authenticity can be called *authenticity of situation*, which we can break down into three sub-dimensions: *authenticity of setting*, *authenticity of role,* and *authenticity of task*. As noted above, most examples of pedagogies of enactment have taken authenticity of setting as a given: most approximations in teacher educations take place in realistic settings like classroom teaching or meeting with parents. From the literature of game-based learning, there are good reasons to believe that games and simulations can support learning in fabricated settings that feel realistic. Games, like much of teacher education (Nolen, Horn, & Ward, 2015), are fundamentally grounded in theories of situated cognition (Brown, Collins, & Duguid, 1989). Gee (2004) posits that well-designed games can situate players perceptually, narratively, and socially in a way that leads to empathetic embodiment for complex systems. Within these deeply situated contexts, teachers can develop new skills, confront prior understandings, and work through problems in an embodied way (Gee, 2007).

Teacher educators, in part of out of logistical necessity, have regularly experimented with differing approaches to *authenticity of role*. To help one novice teacher roleplay as a teacher, other novice teachers need to role play as students, parents, or others. Beyond this logistical value, advocates of role-playing in teacher education have noted the value of role-playing as students, to understand people from diverse perspectives (Gay & Kirkland, 2003), empathize

with the challenges of adolescence, or to remember the particular difficulties that novices face in understanding instruction from experts. Identity has also been a major consideration among game-based learning researchers. Games create opportunities for "projective identities," where the identities and play decisions adopted in a game space are shaped by learners' beliefs outside the magic circle (Gee 2007). As players reflect on their real and adopted identities, they have the opportunity to rethink their beliefs and empathize with others.

Authenticity of task can be defined as the degree to which a given task is an approximation of the real work of teaching, independent of whether or not it takes place in the real setting of teaching. In the violinist's bow game, authenticity of task is maintained by having the correct bow hold be the central objective of the game, even as authenticity of complexity is minimized (the violinist need not read music or bow the strings) along with authenticity of setting (as bow games are designed for practice rather than performance). In teacher practices spaces, authenticity of task means that teachers are deploying realistic reasoning or technique, even as they engage in playfully unrealistic activities.

Our design hypotheses is that moving away from one or more of these dimensions of authenticity opens up a wider design plane for teacher practice spaces with more opportunities for including playfulness. In our design work, we view playfulness as a worthy aim in its own right. Playfulness leads to intrinsic motivation, enjoyment, and engagement (Hamari et al., 2016). From a game-based learning perspective, playfulness creates opportunities for exploration of new identities, beliefs, or techniques in a low-stakes setting. And as Grossman (2009) pointed out, in the context of teacher education, the medium is the message. That is, if a novice teacher can learn how to become an effective teacher in a playful and engaged way, we believe that they will continue to carry out the same approach to learning with their own students.

In what follows we briefly describe early research on five of our practice spaces, and then we provide some examples of how different practice spaces address issues of authenticity, and how dimensions of authenticity interest with playfulness. Playable demos, game materials, curriculum suggestions, and other resources for all of the practice spaces described below can be found at tsl.mit.edu/practice.

Learnings
Baldermath

Baldermath is a bluff-the-judge game about looking at student work (Pershan, Kim, Thompson, & Reich 2017), co-designed by the author of the MathMistakes.org blog (Pershan, 2017), an online space where teachers discuss interesting errors from math students. To play the game, a judge leaves the room, and four players are given a homework problem taken from a fourth-grade classroom. One contestant is given an actual piece of student work for the problem,

completed by a student with an incorrect or incomplete understanding of the problem. This contestant copies the work in her own hand, and then invents a rationale for why the student thought s/he was correct. The other contestants invent incomplete or incorrect answers to the problem as well as their own rationales. The judge returns to the room, and the contestants roleplay as students and explain their concocted rationales along with details of their (fabricated or real) student work. The judge then guesses which is the "real" student work. As with Balderdash or the Wait, Wait Don't Tell Me News Quiz, correct guesses are fun for the judge and incorrect guesses are fun for the winning contestant.

The design of Baldermath is anchored in an authentic task, looking at student work, where expert practice is well-understood by math education researchers. Aside from authenticity of task, the game avoids other dimensions of authenticity. Abridging these dimensions of authenticity seems essential to allowing the playful elements of the game to emerge: participants enjoy trying to think and write like students, and they enjoy employing mathematical reasoning in the service of bluffing and detecting.

Metarubric

Metarubric is a playful examination of the challenges of evaluating complex performance using rubrics (Kim, Rosenheck & Reich, In Submission). Participants select a movie by consensus (such as *Titanic*) and then briefly create movie posters for the selected movie. Participants then create rubrics for the posters, and take turns using their different rubrics to grade the posters. In a follow-up round, players develop a rubric for the rubrics—the metarubric—and then take turns grading the rubrics themselves. In conversations between rounds, players typically observe that their favorite posters do not necessarily get the highest rubric scores, and that most rubrics undervalue a component of their poster that they as creators felt was important. In Metarubric, participants move in and out of different dimensions of authenticity. They play as students and as teacher, creating and grading. The most poignant moments of the gameplay are when participants get low scores on a poster element they feel is done well, and they empathize with learners experiencing how rubric scores imperfectly map onto the worthy qualities of performance assessments. In doing so, participants expand their thinking about how to better align the goals of a learning experience with the assessment criteria for performance assessment.

TeacherMoments

TeacherMoments is a simulation designed for handheld devices, where participants are immersed in short vignettes of teaching life rendered in text, animation or video, and participants respond to scenario "triggers" with text or improvisational audio responses (Owho-Ovuakporie, Thompson, Robinson, & Reich, In Submission). In live-actor clinical simulations used in teacher education (Dotger, 2013), actors are trained to portray parents or students in a specific situation. Briefing books given to actors include the background of the character and

situation, as well as a series of "verbal triggers" that actors are supposed to include in the conversation (such as "You only called me out because you are racist" or "But what will do you when my (autistic) son hugs someone at an inappropriate time?"). Since these actors are meant to create standardized situations, TeacherMoments tests the viability of encoding these interactions entirely in text and video. For instance, Dotger (2013) has developed a series of parent simulations, including one where a parent is upset because a class is too hard; in TeacherMoments, we record six video sequences of an actor playing this parent. Novice teachers participating in the simulation are required to provide improvised audio responses after each recorded conversational turn. In Dotger's live-actor role plays, his four goals for participants are that 1) they experience the interaction as authentic, 2) the scenario generates a feeling of cognitive disequilibrium, 3) participants demonstrate an ability to remain calm under pressure, and 4) they can articulate some element of their teaching philosophy in response to the verbal triggers. Our playtests suggest that these four goals are met within the experience of TeacherMoments, even though our "actor" is pre-recorded rather than live. Given that teachers may never meet a parent during their practicum experience, this application of TeacherMoments gives teacher-learners a chance to practice an important dimension of teaching before their induction period.

Most participants do not experience any of our implementations of TeacherMoments as particularly playful. In part, this is a function of the topics that we've chosen to explore—it may be that examining issues of marginalization and inequity should rarely or never be playful. However, it's also the case that TeacherMoments maintains authenticity of task, of role, of setting, and some degree of authenticity of complexity. Teacher-learners find the experience worthwhile, but not necessarily playful.

Eliciting Learner Knowledge (ELK)

Eliciting Learner Knowledge (ELK) is a two-person online game, with one person role playing a teacher and another role playing a student (Thompson, Roy, Wong, Reich, & Klopfer, Forthcoming). In the ELK platform, players have a conversation through a text-based, chat-like interface. Each round of the game focuses on a conceptual topic in science such as chemical reactions, evolution, or energy, or a topic in mathematics such as rational numbers, fractions, and proportions. At the beginning of the game, each player receives instructions and a brief overview of the game; the person role-playing the teacher receives a learning objective and the person role-playing the student receives a learner profile with details of the conceptions and misconceptions held by the student being role-played. Players review the profiles, engage in a synchronous 7-minute conversation, and then both players take the same true/false quiz as if they were the "student". To encourage collaboration and communication between the players, the quiz is scored on 1) how well the student portrays the student profile, and 2) how well the teacher estimates the student's understanding. ELK has two goals: to help preservice and in-

service teachers understand questioning strategies and to learn about possible student misconceptions.

ELK reduces authenticity of complexity by focusing on a single student-teacher interaction, and asking participants to set aside considerations of the student-teacher relationship and goals for advancing understanding to focus entirely on eliciting student thinking. It maintains authenticity of task, authenticity of role, and authenticity of setting. ELK has more game elements than TeacherMoments, like points, goals, and a timer, but it also rarely gets described by participants as playful.

Committee of N

Committee of N is a design-based card game for exploring education history and policy through school design (Haas, Reich, Feely, Klopfer, 2016). Participants play as consultants charged with designing elements, such as classroom design or graduation requirements, of a new high school. Each Committee of N deck includes eight of these design elements, along with different sets of "value cards" representing belief commitments from the fictional new school. Participants work in pairs, and each round they are dealt hands that include one school design element, and then three school values. Values can include purposes of education (e.g. assimilating immigrants or career/college readiness), theories of learning (e.g. behaviorism to constructionism), instructional methods (e.g. apprenticeship or flipped classroom). A pair might be asked to design the bell schedule for a school inspired by behaviorism, committed to vocational education, and enamored of project-based learning. Pairs create four to eight of these design elements, and then join up with several other pairs to create a school out of their elements. Teams then pitch these joint schools to a panel of "school committee" judges.

For many novice teachers heading out into the field for observations, the elements of a school seem fixed and immutable. Committee of N helps novice teachers see that every practice, every fixture, every routine within in a school was designed at some point in history by people who held a set of values, and if we no longer hold those values we can design new school elements to match our new values. Not every change is equally easy—extra-curricular activities can be redesigned easily whereas most communities can only build a new school building every few decades. Nonetheless, recognizing that school elements were once designed empowers novice teachers to imagine how they might be designed anew. Many students adopt the heuristic of describing the "value cards" underlying the practices and fixtures they see in their school observations. The game mechanic underneath Committee of N is essentially the same mechanic as a Tarot reading: players create stories about the future guided by a series of arbitrary constraints, and by imaging different possible futures, players can reflect on which futures they would like to try to bring about in the world.

Future Directions

Drawing generalizations from small data sets is always a risky endeavor, but nevertheless in the section we set forth three design conjectures that we adduce from our set of five cases. First, authenticity of task is the pre-eminent consideration in the development of teacher practice spaces. Baldermath and TeacherMoments are both rich experiences for novice teachers because the intellectual work in the practice space develops skills and dispositions that support good teaching. Anchoring on authenticity of task may allow for more flexibility in changing other dimensions of authenticity. Even in Committee of N, which seems far afield from the work of teaching, players engage in thinking patterns—imagining different kinds of schools or connecting school elements to their underlying values—that prove valuable in both understanding school environments and navigating change within them.

Authenticity of task is essential, but other forms of authenticity may be obstacles to playfulness. In our set of six practice spaces, TeacherMoments is the least game-like and the most simulation-like, and most teachers don't find the experience playful, even if they do find it meaningful and worthwhile. While the interaction in ELK is quite authentic, players experience the chat-interface as artificial. This allows some element of playfulness, yet it still doesn't feel like a game to most teachers. By contrast, a practicing teacher will never need to fabricate incorrect student work as in Baldermath or use a rubric to evaluate rubrics as in MetaRubric. Yet because of this, teachers' experiences with Baldermath or MetaRubric are more playful. We find in our feedback across playtests of these different environments that typically the closer an activity replicates authentic teaching practice, the less likely it is to feel playful and fun. It may still feel authentic, challenging, and worthwhile, but novice teachers typically do not experience practice spaces that maintain authenticity of setting as playful.

Finally, within practice spaces, we see varying approaches to embedding "good practice" or "expert practice" within the design of game play. The game development process for Baldermath began from a clearly defined construct for looking at student work—with well-defined productive and unproductive practices, and the mechanics of the game naturally guide participants away from unproductive practices and towards productive ones. A simple debrief at the end of the experience may be sufficient for novice teachers to consciously adopt these new practices. Committee of N doesn't scaffold a specific teaching skill per se, but participants learn a useful heuristic—the idea of values underlying a school design element—that can help them better understand the constraints of their context. By contrast, MetaRubric highlights the problems with rubrics without embedding exemplars of better practice within game design. Our hypothesis is that teachers will improve their assessment practices because they empathize more closely with how students experience rubrics and recognize more deeply the tensions in designing effective rubrics. So within the notion of authenticity of task, we see divergence into experiences that deliberately guide players towards expertise versus those that encourage players to "admire the problem." We see promise in exploring both pathways.

In future work, we plan to continue to explore these dimensions of authenticity and playfulness, and explore new ways for preparing teachers with specific skills, dispositions, and knowledge that they can integrate into the complex work of classroom teaching. While player feedback from these games suggests that novice teachers find them enjoyable, provocative and useful, another important dimension of research will be to evaluate whether and how they work in actually improving teaching practice. In future research, we plan to observe novice teachers before, during, and after playing with practice spaces to see whether participation in practice spaces leads to meaningful changes in teacher practice.

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Acknowledgments

Learning to Notice Elementary Students' Ideas and Use of Science Practices in Tool-Supported Rehearsals

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Keywords: science education, teacher preparation, microteaching, rehearsals, approximation

Project Overview

This research focuses on preservice teachers learning to engage in rigorous and equitable teaching in science, and the roles of tool-supported rehearsals in supporting teacher noticing and practice in an elementary science methods course. The rehearsal is an example of a pedagogical approach that draws on representations, decompositions, and approximations of practice. These three pedagogical approaches, as described by Grossman and colleagues (2009), prepare preservice teachers (PSTs) for challenging aspects of teaching in a context, such as a methods course, that is less authentic and less complex than the busy classroom setting. Representations of practice, such as video recordings of instruction, enable preservice teachers to observe key teaching practices in action. Decompositions of practice, such as a set of frameworks and prompts, identify important features that may not be visible to novice teachers. Finally, approximations of practice, like rehearsals, provide PSTs with opportunities to enact and receive feedback on their enactment of difficult teaching practices. These rehearsals are different from run-throughs of lessons that sometimes occur in methods classrooms (Grossman, 2005). In particular, the preservice teachers do not role-play behavioral challenges or simply observe the instruction and offer feedback at the end. Rather, the PSTs and I, as the course instructor, role-play science ideas and alternative conceptions that elementary children might have. I also pause the instruction to provide feedback and to offer examples of common alternative conceptions or challenges children could face in the lesson. Five tools support the teacher-student simulated interactions within the rehearsals[7].

The first tool, the Engage-Explore-Explain (EEE) Framework for Science Teaching and Learning, which is similar to the first three phases of the 5E learning cycle (Bybee et al., 2006), provides PSTs with a vision for effective elementary science teaching. The EEE Framework represents and decomposes science teaching practices and principles that support student learning within three phases:

- Engage phase: Elicit and engage students' ideas with an investigation question
- Explore phase: Support students' observations and data collection explorations
- Explain phase: Help students notice patterns and develop evidence-based explanations

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[7] The rehearsals and associated tools that I used were informed by and adapted from my graduate work at the University of Michigan. The first three tools were originally developed by the University of Michigan Elementary Science Methods Planning Group (Benedict-Chambers, 2016; Davis, 2016; Fick & Arias, in press; Kademian & Davis, in press). After leaving Michigan, I adapted the rehearsals and tools for my own context and continued to develop them locally.

The methods course was designed to provide novices with an opportunity to separately analyze and approximate the practices in each Engage-Explore-Explain phase of science teaching. For instance, the week before the Engage rehearsals, the novices spent a 3-hour class session investigating the practices of eliciting and engaging students' ideas via videos and live modeling, and they co-planned the 20-minute rehearsal with their teaching team and the instructor. The second tool is a student alternative ideas tool. The U-M Elementary Science Methods Planning Group created the list of student alternative ideas to represent research-based misconceptions that elementary students might have about the concepts investigated in each lesson (e.g., Driver, Guesne, & Tiberghien, 1985). For instance, students studying how electric current flows through a circuit may think that the current flows from a battery to a light bulb but not from the light bulb back to the battery. Or, students investigating how light travels may believe that light travels from a person's eye to an object, rather than from the object to the eye. The tool summarizes student ideas and provides an accurate scientific explanation for each idea. The student ideas tools was reviewed in class prior to the rehearsals (Benedict-Chambers & Aram, 2017; Kademian & Davis, in press). Each PST in the methods course selected specific ideas to role-play for each team's rehearsal. As a part of their role-play, they responded to the instruction with alternative ideas and explanations. The teams were encouraged to study the alternative ideas prior to the rehearsals and to include questions in their lesson plans to elicit and respond to the students' ideas.

The third tool is a science practice challenges tool. Anna Arias led the development of an initial version of this tool, as a part of the U-M Elementary Science Methods Planning Group. Similar to the student ideas tool, each preservice teacher in the course selected and role-played a science practice challenge to simulate interactions where children struggled to use the practices as they developed evidence-based explanations. For instance, when recording their observations, students may make inferences rather than observations, or interpret their observations to match what they predicted, rather than what actually happens in the investigation. PSTs studied the science practice challenges prior to the rehearsals and included teaching moves in their lesson plans to anticipate and respond to potential student difficulties.

The fourth tool is lesson artifacts of student thinking. The preservice teachers in the methods course generated these artifacts as they role-played the ideas and actions of elementary students and completed student work. This tool provided the PSTs with an opportunity to integrate the content and practice challenges, treated separately on the two tools, that elementary students might face during instruction. For instance, in the Engage rehearsal, the simulated students may have written predictions that reflected their alternative ideas about the phenomenon or lacked justification. In the Explore rehearsals, students may have recorded observations in a data table to reflect what they predicted, rather than what they saw in the investigation. In the Explain rehearsals, students may have struggled to make sense of patterns in their data or to write claims supported by evidence from the investigation. All of these

artifacts of student thinking were collected and analyzed as a part of the preservice teachers' reflections on their rehearsals. At the end of the semester, the teaching teams taught the same lesson in an elementary classroom, collected similar artifacts of student thinking, and individually analyzed their instruction in a final teaching reflection.

The fifth tool, the EEE Framework feedback form, decomposed the core practices in each phase of the Engage-Explore-Explain science lesson and guided the PSTs' feedback. Following the rehearsals, the class collectively discussed the instruction and how to manage any challenging interactions. After the rehearsals, the novices watched their videotaped instruction and wrote a reflection to analyze their ability to enact the core practices emphasized in that particular rehearsal. Together, these tools guided the course design and scaffolded what core practices the PSTs attended to, and how they reasoned about these interactions, while also providing a structure for engaging in evidence-based analysis of instruction.

Theory of Action

The ability to notice and critically analyze important features of one's practice is a key aspect of effective teaching (Horn & Little, 2010; Windschitl, Thompson, & Braaten, 2011). What and how teachers notice in teaching has been emphasized in recent reforms in science and mathematics education (AAAS, 1993; National Council of Teachers of Mathematics [NCTM], 2000; NGSS Lead States, 2013). While we notice things everyday, these reforms highlight that the noticing required for teachers is specialized (Ball, 2011). In teaching, teachers must identify what is important; make choices about what to focus on; and use principles of teaching and learning to justify their actions (Hiebert, Morris, Berk, & Jansen, 2007; Santagata, Zannoni, & Stigler, 2007; Sherin, Jacobs, & Philipp, 2011; van Es & Sherin, 2002). In science teaching, teachers must attend to students' scientific ideas and sensemaking (Berland & Reiser, 2009). This involves anticipating students' alternative ideas about phenomena before instruction, eliciting students' thinking in discussions, and deciding how to respond (Oliveira, 2010). Science teachers must also notice the ways students use science practices to investigate natural phenomena.

Although preservice teachers spend much of their time in teacher education programs observing their own and others' instruction, learning to attend to what learners think and know is difficult. This research investigates how tool-supported rehearsals can support PSTs in learning to attend to and analyze important aspects of their practice.

Learnings

This research has found that tool-supported rehearsals can provide preservice teachers with opportunities to prepare for, work with, and reflect on how to engage student thinking and use of science practices. This work offers insights about the affordances of tool-supported rehearsals. First, consistent with prior research that has underscored the difficulty of learning to see and use students' ideas in instruction (Jacobs, Lamb, & Philipp, 2010; van Es, Cashen,

Barnhart, & Auger, 2017), this research suggests that PSTs may benefit from tools that help them develop the necessary content knowledge and pedagogical content knowledge (Avraamidou & Zembal-Saul, 2010) to work with student ideas. In classroom settings, many factors compete for teachers' attention, and focusing on the nuances of children's thinking may not be prioritized (Sherin et al., 2011).

Second, as others have reported (e.g., Lampert et al, 2013), this work reveals that rehearsals allow preservice teachers to experience and learn from mistakes. It is much better that the PSTs realize that students have ideas that need to be elicited and supported after their first rehearsal, than realizing that in the classroom where students' learning could be impacted (Grossman et al, 2009). Moreover, recognizing their assumptions about teaching and student learning prior to teaching in classroom contexts is an important benefit of the rehearsals. As teacher educators, we want to design learning experiences that enable preservice teachers to face their assumptions and to learn from their mistakes, but to do so in the safety of the methods course classroom.

Third, this research builds on prior studies by showing that even though the PSTs recognized the artificial nature of the rehearsal, they valued the learning opportunities afforded by the simulated interactions (Grossman et al., 2009; Lampert et al., 2013). Although rehearsals are designed to engage PSTs in instructional interactions that are less authentic than those they would encounter in a complex classroom setting, PSTs may become frustrated with the inauthenticity of rehearsals (Benedict-Chambers, 2016; Stroupe & Gotwals, 2017). They may not embrace the learning opportunities afforded within the approximations of practice because they don't understand the goals of rehearsals. After recognizing that the PSTs in my science methods course struggled to understand the goals of the rehearsals, I created a new tool that outlines the challenges they might face in preparing for, enacting, and reflecting on their rehearsals and the opportunities for growth. I introduce this tool at the beginning of the course and then revisit it at the end, and the PSTs have shared that this helps them to understand the rationale for the rehearsals. Another explanation for the PSTs' buy-in may be that the tools enabled them to recognize the complexity of teaching and the challenges their students might face in instruction in the elementary classroom. As such, they appreciated their classmates' simulated responses to their instruction and the deliberate practice that afforded.

While rehearsals will never replace the need for PSTs to engage with students in classroom contexts, the simulated teacher-student interactions can highlight important features of science teaching and learning, prepare PSTs to manage some of the complex aspects they might face in practice, and help them reflect on specific elements of supporting student sensemaking.

Future Directions

- More research is needed to study how preservice elementary teachers carry their tools and their skills of noticing into classroom contexts.
- Research should examine the connections between peers' use of the tools to simulate elementary student thinking in the rehearsals, PSTs' perception of the authenticity of the rehearsal experience, and their ability to attend to and analyze important aspects of science teaching and learning.

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Maximizing Data Collection During a Teaching Observation, and For Analysis, Feedback and Reflection in the Context of Teaching Simulations Using an App-based Tool

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Keywords: science education, mathematics education, teacher preparation, assessment, microteaching

Project Overview

The positive effects of using teaching simulations as an activity to help improve instructional skills has been established. But, improvement is dependent upon two key participants: a) the person teaching - a participant with the goal of improving instruction, and b) the observer - the participant with more advanced knowledge of teaching, who can contribute with poignant observations and specific feedback, much of which is currently qualitative in nature. This project is designed to address the need to upgrade the observation, analysis and feedback part of the simulation, by using more quantitative data collection as a primary source for the feedback provided to the teacher, which then lays the groundwork for evidence-based reflection, and for establishing future quantitative targets for teaching.

Theory of Action

Preparing teachers how to teach effectively and engaging learners at high levels involves complex tasks that sequence knowledge and awareness, practice, observation and data collection, followed by analysis and reflection, an essential process for change in teaching practice. Embedded into the complex act of teaching are numerous teacher and student actions and responses, occurring in a short amount of time, so much so that novices are left with general impressions and memories of their actions during the teaching episode.

Pre-service teachers and teacher preparation programs share a need with practicing teachers and administrators, for using more quantitative indicators of teaching during the assessment process, and that such feedback is more evidence-based in nature. Data collected during a simulated teaching session (from video or real-time) can include: 1) types of questions and responses, 2) average and specific wait-times, 3) specific type and length of teaching strategies utilized, 4) specific type of interchange between students or general student participation, 5) predominate patterns of interactions between the teacher and students, 6) misbehavior data to the individual student level, and 7) teacher intervention to misbehaviors whether to the individual or whole group. These are all factors that can be observed and noted during an observation, and used during the analysis and feedback phase.

However, the problem is collecting the data without using more than one observer, and without experiencing cognitive overload, while maintaining a collaborative learning

environment. Research shows that technology use supports collaborative learning and when teacher candidates are provided opportunities to reflect upon and discuss classroom practices their understanding of the teaching situation deepens (Brookfield, 1995; Bruce & Levin, 2003; Hughes & Mapes, 2012; Lee & Young, 2010; Martin, 2005; Matthew, Felvegi & Callaway, 2009). Pilot efforts to gather substantially more quantitative data during an observation have been successful (Ashmann and Berg, 2013; Berg, Scolavino, Ashmann & Dieker, 2017).

As such, the challenge focused on during this project is to maximize quantitative data collection during observations that allows for rich analysis of a set of critical factors that set the foundation for robust feedback and self-reflection. Based on prior work, and recent efforts, the solution to the problem stated above might include incorporating web-based app technology to collect and analyze data while providing many different visual representations including tables, graphs, and heat maps of seating charts to use in the feedback process.

Learnings

Pilot use of the technology indicates that data collected during a teaching simulation can include all of what is mentioned above, and more. Data collection can be extensive without reaching cognitive overload, and data analysis is instantaneous upon completion of the observation, with critical factors displayed in various visual representations. Feedback to the teacher can include:

   A complete profile of all teacher actions and teacher-student interactions in the lesson to show predominance of behaviors and teacher tendencies
      What types of questions were asked by the teacher, and how many of each type.
      What types of teacher responses followed student actions, and how many of each type
      Wait-time averages in general, and specific wait-times for each teacher and student action.
   A complete profile of all student actions showing interactions with the teacher, with other students, and student misbehaviors
      Which students are interacting, which are passive? Are most questions answered by a few students, while the other students are satisfied to be non-responsive throughout the lesson? Did the teacher employ strategies that engaged most or all students?
      Were students with special needs, or ELL students engaged at a level comparable to regular education students?
   An analysis of the data uncovering the critical patterns of teacher-student interactions
      When teachers ask questions and students respond, is it a productive pattern, or one contrary to the goals of the lesson. If student engagement and thinking is the goal, are open-ended questions present or absent, or were all follow-ups to student responses teacher-clarifying instead of asking the student to further explain their answer?
   A complete profile of student misbehaviors and how the teacher dealt with such behavior.
      Are misbehaviors initiated by a few students versus many, or were there many misbehaviors without a teacher intervention?
      What if misbehavior counts are high during x type of lesson, and low during y type of lesson?

Summary

With simulations (or live instruction) a substantial amount of quantitative data can be gleaned by one observer from a teaching episode and be a source for critical feedback to the teacher. Since many observers are mostly grounded and attuned to the qualitative aspects of observation and feedback, the very act of using the technology and engaging in quantitative data collection with related feedback, is similar to having a new lens from which to view instruction, which can affect both teacher and observer in a positive manner, and contribute to the impact of using a simulation to help improve teaching skills.

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Pre-service Middle School Science Teachers' Practices of Leading Discussion with Virtual Avatars

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Keywords: Science education, teacher preparation, approximation, live simulation

Project Overview

The field of practice-based teacher education (PBTE) is shifting toward establishing a common language for teacher education (McDonald, Kazemi, & Kavanagh, 2013) focusing on instruction grounded in high expectations for all students (Forzani, 2014). This vision is driven by descriptions of high-leverage practices (HLPs). Leading a discussion has been described as an HLP of teaching (Ball & Forzani, 2009) and is associated with other HLPs of eliciting and responding to students' thinking (Robertson, Scherr, & Hammer, 2016), especially since, during classroom discussions, the teacher has many opportunities to elicit and respond.

The Next Generation Science Standards (NGSS) describe a vision of proficiency in science based on a view of science as both a body of knowledge and as way of knowing. Learning science, in this view, involves not just learning conceptual content, but also learning to engage in scientific practices, such as constructing explanations and engaging in argumentation (NRC, 2013).

We believe teacher educators can prepare science pre-service teachers (PSTs) to engage with HLPs to support the goals of NGSS, and it is important for PSTs to have opportunities to practice leading discussion. One avenue to pursue this work is the use of approximations of practice, which provide opportunities for PSTs to practice teaching in a controlled environment (Grossman et al., 2009). We report on research on one particular kind of approximation: the use of virtual "avatar" students in the TeachLivE™ environment (Dieker, Hynes, Hughes, Hardin, & Becht, 2015), and explore how PSTs engaged the avatars in constructing explanations for scientific phenomena. We are interested in whole-class patterns, addressing the following question: In what ways were PSTs similar and different in eliciting and responding to avatar student thinking? We also explore selected PSTs' discussions in greater detail: In what ways were PSTs' goals for the discussion connected to their practices? In closing, we consider how these similarities and differences can inform opportunities and new directions for teacher education.

Theory of Action

The turn toward HLPs and PBTE is driven by theoretical views of teaching as situated and interactional (Russ, Sherin, & Sherin, 2015). To become competent in HLPs, PSTs require

practice in settings that approximate the diversity of interactions that arise in the complexities of classrooms. Our theory of action is aligned with these views.

Teaching responsively and leading discussion in productive ways have been found to be challenging for PSTs (Blanton, Berenson, & Norwood, 2001). There is also evidence, however, that PSTs can elicit and respond to student thinking during discussion given support and opportunities to do so (Grosser-Clarkson, 2016; Levin, Hammer, & Coffey, 2009). We take this perspective, supported by evidence, that HLPs of leading discussion and responsive teaching are possible for PSTs to enact in an approximation of practice.

The TeachLivE approximation with the avatars (Dieker et al., 2015) allows a safe, relatively controlled, but dynamic situation in which PSTs can practice leading discussion responsibly. In practice, in the classroom, responsive teaching in discussion can be influenced by a variety of factors (Lau, 2010; Robertson, RIchards, Elby, & Walkoe, 2016; Rop, 2001). In this paper, we focus on the PSTs' goals for the discussion, because these are short interactions in a simulated context and other features are not as salient. Looking at whole class data, and then at individual PSTs, we consider how goals for the virtual discussion align with how PSTs elicit and respond to students' thinking. We hypothesize that goals that are aligned with attention to the substance of students' scientific thinking will be associated with responsive practices.

The participants in this study were 13 PSTs in an undergraduate mathematics and science middle school program. The avatar sessions took place during a science methods course taught by the first author in the semester preceding student teaching. Toward the end of the course, PSTs approximate a responsive classroom discussion with the avatars. Other activities of the course align with instructional strategies supported by theoretical and empirical work in the PBTE literature (e.g., McDonald et al., 2013).

The avatar approximation is a virtual classroom with five diverse students with different voices, mannerisms, and learning profiles. The PSTs in the methods class generated four questions designed to engage students and PSTs were divided into groups, so each person had the opportunity to lead two ten-minute discussions around two of the four questions, spread one week apart. In this short paper, we only discuss one of these questions: "Why does grass smell when it's cut?" The other three are in Appendix A. In a paper following the simulation, PSTs are asked to comment on particular student ideas that stood out for them, to analyze their own responses to these ideas, and to describe how it felt to lead the discussion.

We video recorded the discussions and one author took field notes, in order to give PSTs material for remembering salient parts in the discussion. We transcribed the 26 recordings and used the four PSTs' analyses of the discussion as a second data source to understand their professed goals.

To address our first question about whole class patterns, we analyzed the data for responsiveness, beginning with deductive codes (Miles, Huberman, & Soldana, 2013) derived from Pierson's (2008) study of responsiveness among secondary mathematics teachers. We modified the details of Pierson's categories to be more appropriate for science by practicing with avatar data from the previous year's discussions. We coded for "responsiveness" (Low, Medium, High I, High II) and "intellectual work" (Give Low, Give High, Demand Low, Demand High) (Appendix B). The coding unit was each teacher candidate's meaningful, content relevant response. Each of these units was coded with both a responsiveness and an intellectual work code. An example of a coded response would be (HII/IDH). Two authors coded eight of 26 transcripts chosen randomly to calculate inter-rater reliability. Reliability was 79%, and rose to 85% for HII/IDH codes, which made up 40% of the codes. Drawing from a previous project (Fleming, Grosser-Clarkson, Levin, & Chin, 2018) we followed a procedure of highlighting the row or column(s) capturing at least 50% of codes. This procedure helped us to identify different profiles for the two discussions for each PST (Appendix A).

To address our second question, we purposely selected (Maxwell, 2012) four PSTs, representative of the overall diversity, and who were also candidates who we were following in their student teaching placements. We met together regularly to review videos of the four PSTs and examine their analysis of their teaching for evidence of their goals using a holistic approach described by Robertson et al., (2016b) to generate themes of the specific ways in which the PSTs approached the discussion and whether and how it was aligned their stated goals.

Learnings

Appendix A shows four of the 13 candidates had HII/IDH profiles in the first discussion and six in the second. 7/13 candidates had HII profiles and 9 had IDH profiles in the second discussion. Additionally, there we many cases in which candidates had a lot of HII/IDH codes, but did not meet the 50% criteria. The high proportion of HII codes (and also few "Give" codes) suggests a shared understanding among the candidates that they were not expected to lecture or to "tell" the answer (Chazan & Ball, 1999)

Alexa

Alexa asked the avatars the grass question directly and gave them a brief period to think before she asked for volunteers. About two minutes into the discussion, a student presented an analogy to opening a bottle with scent.

In lines 2 and 4, Alexa's responses suggest she is guiding the students (Appendix C). She appears not to pick up on the "particular reason" for the smell Savannah gives within her analogy, but clarifies in line 4 she is asking students to say what happens to the "individual piece of grass". She introduces her own idea to move students forward. In contrast, in response to Ethan saying

the grass is severed in half, she asks Ethan to explain why the grass is smelling (6) and probes further to ask him to explain his idea that the grass is trying to heal itself (8). Ultimately, she asks the other students to consider Ethan's comparison to the healing process in the human body (10). Using Pierson's coding scheme, we coded lines 2 and 4 as HI and lines 6, 8, and 10 as HII.

A commonality in Alexa's discussions was a tendency to ask questions, elicit students' ideas, and use these ideas to guide them in constructing an explanation. As pieces of an explanation got constructed, she frequently asked for students to "agree or disagree".

Alexa often alternated between guiding and probing individual ideas, as shown in the transcript. This pattern is consistent with what Alexa described as her goal for the discussion in her analysis: "Most of my facilitation was focused on the goal of getting students to respond to each other's thinking and to really listen to what they are saying." The transcript also suggests a tacit goal of "making progress", as Alexa's questioning suggests she is pushing students toward finding consensus for pieces of an explanation.

Matt

Matt often seemed to struggle with coherently eliciting student thinking and responding to the ideas with questions. For example, he launched the grass question hesitantly, as shown in the Appendix C, and the question was apparently unclear to the avatars (lines 2 and 3).
Later in the discussion, Dev mentions the smell might be caused by "a chemical reaction". Matt says Dev's idea was "a possibility" before soliciting ideas from Jasmine and Eva. Then Matt summarizes the ideas he heard.

Some of Matt's responses in this transcript, such as line 17, were coded as High II responsiveness and high intellectual demand. However, although in line 18 Eva says she agrees with both Ethan's idea (the smell is caused by "grass juice") and Dev's idea (it's due to a chemical reaction), Matt pursues Dev's idea only, and based on Eva's summary alone suggests "that's something we've decided on and agreed upon". Matt treats the discussion as though it were closed and states "maybe we can look at the next question".

From this point, Matt begins to assert his own ideas (HI), apparently steering the conversation in another direction. In lines 19 and 21, he seems to be asking for an adaptive benefit to the grass, assuming the chemical cause of the smell has been explained. He then begins to introduce his own reasoning by providing the idea to create an analogy (26). Although Matt was sometimes responsive to students' ideas, he tended to give students his own ideas frequently. He appeared to have a pre-set plan of what he wanted to ask, and often disregarded students' thinking in carrying out this plan.

In his analysis, Matt confirmed his goal to "identify" particular ideas. He also noted his goal to use his analogy, apparently to shift students to think about the adaptive significance. He noted the "entities" he wanted them to identify "were brought up in the discussion;" but it was he who brought them up.

Future Directions

This study supports findings from other research on responsive teaching in showing many PSTs are able to elicit and respond to student thinking in productive ways during discussion. In addition, this confirms our previous work showing individual differences between PSTs can be detected in the simulation, and some PSTs are able to elicit and respond to student thinking in productive ways (Levin et al., 2018). Comparison between Alexa and Matt shows different patterns, corresponding to different goals. Whereas Alexa tended to guide the students to a point where they could express ideas for her to respond to, Matt tended to elicit student ideas and then provide his own, to guide students in a particular direction. These findings are particularly useful as reminders of the variety of goals that influence PSTs' practice.

As an approximation of practice, coming just before the student teaching internship, the avatar experience, and the analysis of it, can be a useful resource for teacher educators as they consider how to support individual candidates as they enter their internships. Teacher educators can communicate with classroom supervisors/observers to provide insight into how to help particular PSTs develop HLPs of leading discussion and eliciting and responding to students' thinking. Matt, for example, could be supported in better planning the questions he asks to launch the discussion, and in balancing his own goals with attention to students' ideas. Alexa, already attuned to students' thinking, and with her interest in guiding discussion toward consensus, could be encouraged to engage students in argumentation with others' ideas, moving herself to the side and facilitating more student-to-student discourse.

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Appendix A

Questions

1. What causes the grass to smell when it's freshly cut?
2. What causes it to snow?
3. What causes rainbows?
4. What causes leaves to change color?

Whole class data

Key:

* indicates selected PST

-- indicates no dimension greater than 50% of codes

Student	First Avatar	Profile	Second Avatar	Profile
"Alexa" *	Grass	HII/IDH	Snow	HII/IDH
"An"	Snow	L	Rainbows	IDL
"Arlene"	Rainbows	HII/IDH	Grass	HII/IDH
"Courtnee"	Snow	HII/IDH	Rainbows	HII/IDH
"Dean"	Snow	L/IDL	Leaves	L
"Evan"	Snow	L	Leaves	IDH
"Kelly"	Grass	IDH	Leaves	HII/IDH
"James"	Snow	IDL	Leaves	HII/IDH
"Matt" *	Grass	--	Rainbows	IDL
"Nina" *	Grass	HII/IDH	Rainbows	HII/IDH
"Nomi"	Snow	HII	Leaves	HII/IDH
"Sabine" *	Snow	L/IDL	Rainbows	L/IDL
"Sharon"	Rainbows	--	Leaves	IDH
Fraction RL		4/13		2/13
Fraction IDL		3/13		3/13
Fraction HII		6/13		7/13
Fraction IDH		5/13		9/13
Fraction HII/IDH		4/13		6/13

Sample profiles from four selected candidates

Key:

* indicates categories of responsiveness (columns) or intellectual demand (rows) that total 50% or more of all codes

Alexa (Grass)	Low/No	Medium	High I	High II
Give Low	0	0	0	0*
Give High	0	0	1	0*
Demand Low	1	0	0	0*
Demand High*	4*	0*	3*	14*

Matt (Rainbows)	Low/No	Medium	High I	High II
Give Low	0	2	0	0
Give High	0	0	0	1
Demand Low*	8*	7*	7*	0*
Demand High	0	0	0	11

Sabine (Snow)	Low/No	Medium	High I	High II
Give Low	0*	0	0	0
Give High	0*	1	1	0
Demand Low*	10*	1*	0*	0*
Demand High	2*	0	0	5

Nina (Grass)	Low/No	Medium	High I	High II*
Give Low	0	1	4	0*
Give High	0	0	0	2*
Demand Low	6	5	0	0*
Demand High	0	2	3	24*

Appendix B

Modification of Pierson's Coding Scheme for Intellectual Work and Responsiveness

Intellectual Work
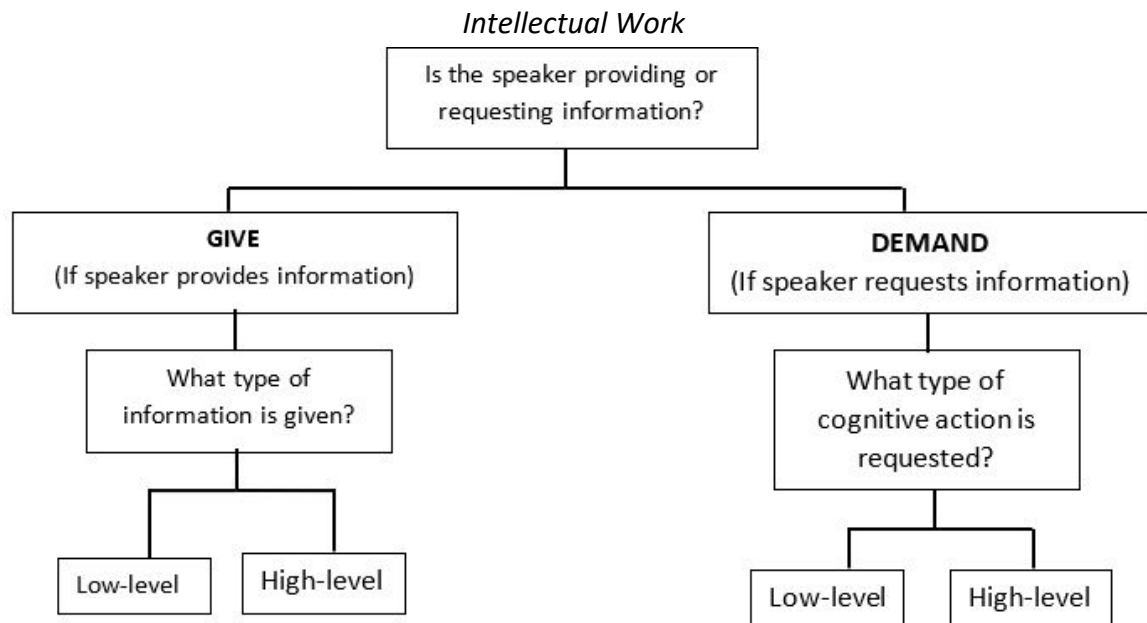
Give Low

- Evaluation
- Rebroadcast
- Incorrect or confusing info
- Direct explanation
- Tell result process or procedure
- Confirm

Give High

- Summary of student or more than one student's idea
- Summary of discussion
- Amplifying particular ideas
- Describe thinking strategy
- Interpret data or hypotheses
- Compare, contrast, or connect
- Provide example, counterclaim, or counterexample
- Make judgment between claims

Demand Low

- Fact, recall, terminology,
- Multiple choice
- Encouragement
- Request for different responses, without asking for interpretation.

- Any Y/N question unless there is an obvious genuine pause for student to clarify meaning.

Demand High
- Request to explain reasoning
- Request to interpret others' idea ("do you agree"; "does her explanation make sense")
- Open-ended questions (What do you notice…)
- Request for hint, example or counterexample
- Request to predict
- Request to compare, make connections and generalize

Responsiveness
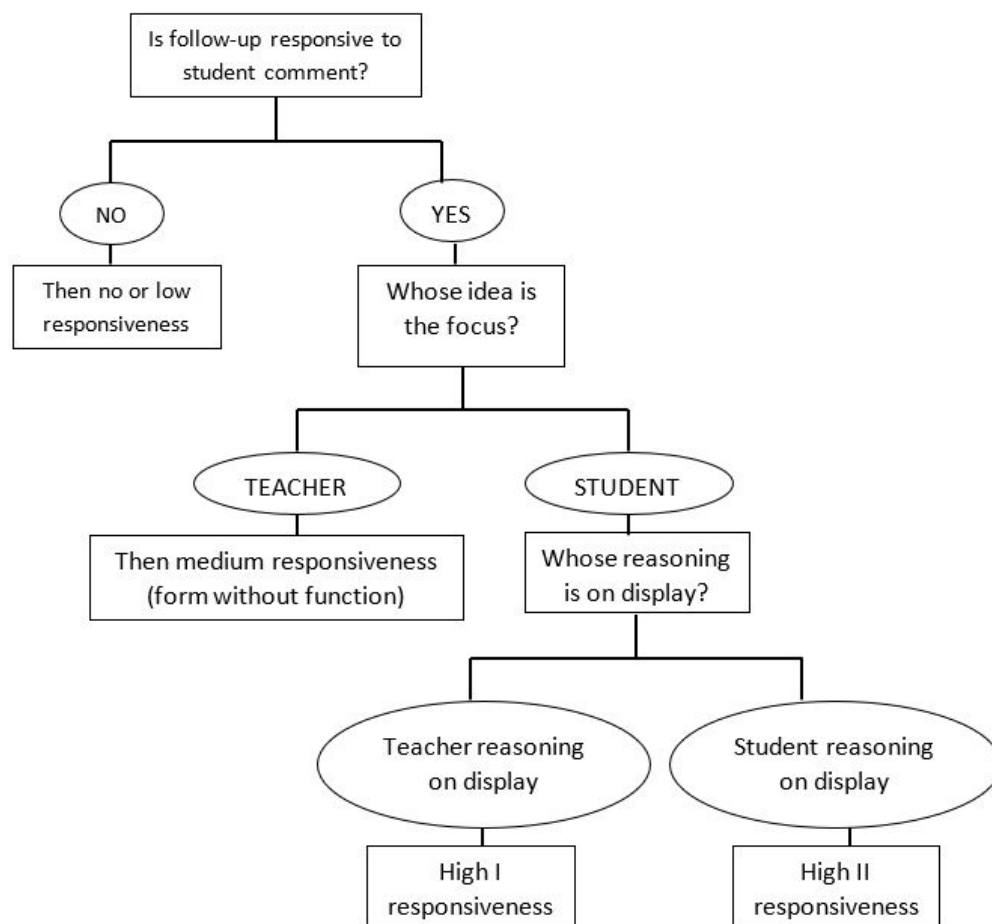
No/Low
- Evaluation
- Rebroadcast
- Acknowledge
- Related Stmt/Question
- Repeated Question
- Request to share new idea

Medium

- Corrective (gives answer)
- Brush off idea/not sincerely engage
- Prompts to provide additional information toward correct idea
- Uses S comment to give instructions
- Coopt students' idea, but idea is teachers
- Y/N question with pause for response
- Rebroadcast as a question
- Request for different responses, without asking for interpretation.

High I

- Genuine attempt to respond to student's idea.
- T reasons about or expands on student's idea.
- Pursues students' idea to correct error. S is asked to make sense of T's reasoning.
- T answers S question

High II

- Invitation to make sense of others' ideas, even if response could be y/n.
- Probing students' thinking to understand meaning
- Probing for mechanistic detail
- Encouraging argumentation
- Take up student thinking by asking for repeat and clarification, elaboration, etc.
- Pushing student to consider a counter example, "What if someone said…?

Appendix C

Transcripts for "What causes grass to smell when you cut it?"

Alexa

1. Savannah: Like, if you, like open a bottle from Bed Bath and Beyond, like, okay. So if you grab a bottle from Bed Bath and Beyond, you can probably smell the stuff, but if you open the bottle, and then you can really smell it. So maybe it's like you have a piece of grass and it smells like grass, but then you cut the grass then it really smells like grass.
2. Alexa: Okay. Interesting. Do you think that the grass is smelling for a particular reason?
3. Ethan: What do you mean?
4. Alexa: What's happening to the grass when it's being mowed? What happens to the individual piece of glass when you, grass when you mow it?
5. Ethan: It's being severed in half.
6. Alexa: It's being severed in half. That's a good idea. So knowing that, do we have any ideas about why the grass might be smelling?
7. Ethan: Is it, like, trying to heal itself?
8. Alexa: Maybe. Why do you think that?
9. Ethan: Because it's being cut in half, then that probably hurts. Like, the body's normal reaction when you, like, it's like when you cut yourself and you bleed, your body tries to heal where spot is cut. So maybe um, maybe the grass juice and the grass smell are letting the grass know hey man, it's okay, you'll be all right, tomorrow's another day, you're gonna be fine.
10. Alexa: All right. So Ethan's comparing it to when you've cut yourself and your blood cells go to the cut to try to get rid of the bac-, bacteria and heal the wound. Does anyone agree or disagree with what Ethan's saying? Jasmine, you haven't spoken in a while. Do you have any other ideas?

Matt

(Beginning of discussion)

11. Matt: So today we want to w-, wonder why when, when, when grass it cut what happens to the ... what is the, what ... When grass is cut by a lawn mower, um... what happens with the, with the smell of the grass in the air?
12. Jasmine: What?
13. Savannah: What causes the smell of grass?
14. Matt: What causes the smell of green grass when it was cut?"

(Later)

17. Matt: Let's restate what Dev said. Dev said there was a chemical reaction and you think that is a dye and Ethan said that it had a smell and Jasmine and Eva said it had a different type of smell maybe from another source. So let's really concentrate on where

the source of the smell came from. Do we have a consensus about that? Would you like to discuss that?...Okay. Any ideas? Eva, do you want to summarize where we are right now?

18. Eva: I kind of think basically everyone's saying that whenever this juice is, like Ethan was talking about is, like, a chemical reaction like Dev was talking about, and that's what happens normally.

19. Matt: Okay. So if that's something we've decided on and agreed upon, maybe we can look at the next question is why does it happen and is there any, any, any benefit to the grass for that, for that occurrence? Do you want to think about that for a moment?

20. Eva: I didn't understand.

21. Matt: Well, let's just say the grass was randomly harmed and it releases this chemical reaction. Is there a mechanism that it could either benefit or hurt the grass in the future?

22. Matt: Would there be other plants, um, that do something similar?

23. Dev: Like a Venus flytrap, like when you reach up to play with it, it closes up.

24. Matt: Well, in that case you're talking about a plant an animal and a relationship there. So is there another way we can look for a relationship between the grass and other bugs or animals and see if there's some cause or a relationship there?

25. Ethan: I think if you've got a Christmas tree and it smells like Christmas.

26. Matt: It smells like Christmas? Okay. Let see if maybe we can design an analogy for this. Let's just say the grass is like a, uh, metropolis. Lots of people in a metropolis. And something comes along and harms one other person. Is there a way that we can communicate, to ask for help?

27. Savannah: Metropolis? I don't understand.

28. Matt: Okay. I was, I was gonna propose an, an analogy to a grass and being a population and trying to think of a story of how the grass might be calling for assistance or, or, or some other action to, to help it. Is there a story you can make about something similar to that?

Rehearsals of Teaching: A Simulation of Complex Practice

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Keywords: mathematics education, teacher preparation, role play, rehearsals, approximation, live simulation

The Learning in, from, and for Teaching Practice Project[8]

Project Overview

The Learning in, from, and for Teaching Practice (LTP) project is a practice-based model of teacher education that, in close collaboration with school districts, provides repeated opportunities for pre-service teachers to move back and forth between enactments of teaching and investigations of the practices, knowledge, and principles of high quality teaching involved in those enactments. The model includes the use of intentionally selected instructional activities that are designed to travel back and forth between methods courses to enactment in schools. The instructional activities scaffold novice teachers' efforts to work on various instructional practices (such as eliciting student thinking and orienting students to each other's ideas) in connection with one another and with principles of learning and teaching. These activities operate within consistent participation structures that give school children multiple entry points (such as asking students to notice and describe patterns during Choral Counting) and promote participation that is not solely dependent on talk.

Central to this model is the pedagogy of rehearsal, which provides novices with guided opportunities to both simulate and analyze manageable chunks of contingent, interactive practice before enacting them with students in classrooms (Lampert et al., 2013). During rehearsal, one or more novice teachers (NTs) participate as teachers while other NTs participate as students, exhibiting their understanding of how children think about mathematical ideas, and simulating the multiple relationships with students and content that might be in play. Through their participation, NTs often contribute insights and questions related to the routine and spontaneous instructional interactions that must be managed in teaching. Guiding participation during the simulation, the teacher educator acts as both coach and simulated student, enabling them to put into play a range of issues related to students, subject matter, and instructional decision-making. Norms are established so that the teacher educator has the opportunity to stop action and provide in-the-moment feedback as the NT deliberately practices moves that are responsive to specific and multifaceted student actions. Brief discussions can also take place among the participants in which decisions are weighed and alternatives considered. Rehearsals are not scripted; they simulate many different relationships

between students and content that might emerge in teaching, requiring the rehearsing teacher to make both routine and improvisational decisions in practice.

Theory of Action

The LTP model is based on research on the development of adaptive performance, which suggests that there is a continual back and forth between repeated practice of a set of skills and learning how to use them adaptively in different situations (Hatano & Inagaki, 1986). This theoretical perspective is a basis for the Cycles of Enactment and Investigation, in which all rehearsals are embedded. A given cycle begins with NTs observing and analyzing an enactment of an instructional activity, either live or on video, in order to identify teaching practices and discuss the professional commitments of ambitious teaching that guide their use. Next, NTs prepare to teach the activity, rehearsing it publicly in front of their peers and the teacher educator. During the simulation, NTs practice and learn when and why to employ particular practices guided by mathematical knowledge for teaching and teaching principles (such as treating all children as capable of making sense of mathematics and giving them access to important mathematics). All NTs then enact the instructional activity with actual students in elementary school classrooms, video-recording their work. Continuing the cycle, the teacher educator guides collective analysis of these enactment records to examine how teaching practices were (or could be) guided by principles of ambitious teaching and the extent to which mathematical goals were addressed.

Based on this theory of action, teacher learning is viewed as development over time of proficiency with particular practices along with an understanding of their purposes and the principles that guide their use. The cycle of enactment and investigation is designed to support this development over time, assuming that in doing ambitious teaching and analyzing it, novices learn through building an iterative and interactive relationship between knowledge and principles on the one hand, and practical tools on the other (Grossman, Hammerness, & McDonald, 2009).

Learnings

In an analysis of 90 rehearsals occurring across three teacher education programs, we presented both quantitative and qualitative data to analyze how teacher educators (TEs) structured rehearsals to attend to the complexities of decision-making. We found that rehearsals averaged 15 minutes in length and included many pauses so that the teacher educator and the NT could communicate about instructional decisions in the midst of the act of teaching. We identified four broad categories of roles that the TE played during rehearsal: (a) providing directive feedback, (b) providing evaluative feedback, (c) scaffolding enactment, for example, by making a needed teacher move or acting as a student, and (d) facilitating a reflective discussion of instructional decisions within the rehearsal. We also found that rehearsals afforded opportunities to work on many different aspects of practice in relation to

one another, suggesting that rehearsals as a simulation of teaching support work on complex practice (Lampert et al., 2013).

In an analysis of 30 rehearsals, also using both quantitative and qualitative data, we showed how rehearsals afforded multiple opportunities for novices to engage in tasks of teaching that enlist Mathematical Knowledge for Teaching (MKT), such as posing questions to elicit student explanations and to connect different strategies, and using representation to attend to the mathematics. The results also revealed how the teacher educator used four different types of interventions to support work that enlists MKT: Noting affordances and constraints of instructional moves, providing insights into the mathematics or students' thinking, facilitating and unpacking the mathematics, and guiding instructional decisions to attend to the mathematics (Ghousseini, 2017). The significance of these findings for rehearsals as a simulation is its affordance for work on substantive knowledge like MKT alongside work on instructional skills.

Future Directions

Some of the open questions that we continue to consider are:

1. How do we determine quality in teacher education pedagogies like rehearsals as we begin to explicate and specify them?
2. Can quality be enhanced and assessed within a system of pedagogies that are connected to each other through common tools (like the instructional activities in our model)? See for example the work that our LTP colleague Elham Kazemi developed at the University of Washington as represented by TEDD.org).
3. How do we determine what can be productively simulated inside rehearsal (what grain size of practices?) Our developing hypothesis with regard to this last question is the level to which what is simulated attends to the integrity and complexity of teaching.

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SHIFTing Horizons in Future Teachers With Simulated Encounters

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Keywords: Teacher preparation, approximation, live simulation

Project Overview

The SHIFT Project stands for *shifting horizons in future teachers*, pulling on concepts from philosopher Hans George Gadamer (1960/2011) related to being "pulled up short" in moments when expectations are unmet. In this project, we use live-actor, video-recorded, group-debriefed simulated encounters to engage pre-service teachers (PSTs) in an hermeneutic process that focuses on prejudice and the changing nature of individual understanding of systems of oppression. Simulated encounters involve a live interaction between the PST and an actor who has been trained to play the role of a student, parent, or coworker in a standardized way. These encounters simulate discretionary moments in teaching, with particular attention to moments in which the sociopolitical, cultural, or historical aspects of the interaction are especially salient. Interactions between PSTs and actors are video-recorded and then used as part of a sensemaking process (Weick, Sutcliffe, & Obstfeld, 2005).

We use "simulation" to refer to a cycle of instructional tasks that occur each time a simulated encounter happens that draws on ideas set forth by Dotger (2013). Each simulation cycle has five tasks: 1) the TIP + pre-reading; 2) the encounter; 3) the raw debrief; 4) the video + re-reading; and 5) the group debrief. The cycle first begins in the class session prior to the encounter, when PSTs receive a written Teacher Interaction Protocol (TIP) that includes background leading up to the moment being enacted. Prior to the encounter, PSTs respond to a series of "pre-reading" questions (drawing on Freirean (2005) notions of "reading the world") that ask them to envision what will happen in the encounter and ground that in details from the TIP as connected to assigned readings for class. The simulated encounters themselves are "approximations of practice," putting PSTs in a moment of teaching they are likely to encounter again – talking with students about academic or behavioral concerns; meeting parents who have concerns about their students or who have been called in to hear teacher concerns; or visiting a coworker to get their perspective on a group of students or new policy. The broad scope of the encounters, however, are always situated in particularities that make them quite specific – at a school located in our local area, in a certain grade and content area in some instances, with a prior history for the student or parent, including racial/ethnic/linguistic/religious or other background that the PST may not necessarily encounter again. Encounters happen individually, with only the PST and actor(s) present, but are video-recorded. These last 10-12 minutes. Immediately after the encounter, participants gather in small groups of 2-4 to do a "raw debrief" in which they share what happened in their encounter and how they feel about it in the immediate aftermath. Within a few days of the encounter, PSTs then receive access to their own video-recording and are asked to watch it and respond to a new series of

questions that ask them to look again at the interaction, often with an emphasis on particular aspects of the encounter. Finally, in the class session that follows the simulated encounter, instructor guide PSTs through a group debrief that helps them (re-)see the encounter, re-interpret what happened, reconsider how they might act if they were to encounter such a scenario in the future. The group debrief is heavily structured, moving the group towards a shared vision of the encounter, as situated in systems of oppression, while recognizing the array of possible responses. In addition to this cycle of tasks, a "simulation" as we use it is always situated in a particular licensure course, at a moment in the course at which the encounter can be used to support teachers' sensemaking of particular concepts. Our goal is not to move teachers toward a vision of *the* "right" way to respond to the scenario, but a more nuanced understanding, set in commitments to anti-oppressive education, of what constitutes a *responsible* way of responding, with a clear recognition of how their own positionality may come into play.

Thus far, pre-service teachers are the main participants, though we have had a small sample of in-service teachers participate in select simulations as part of professional development. Our primary goals with this project are to help PSTs make sense of the uncertainty, discomfort, and even fear they experience in the encounters that make them more likely to replicate the status quo and existing inequities in our education system. We refer to this as developing a stance of pedagogical responsibility (Stengel & Casey, 2013). The emphasis on (re)interpreting the simulated encounter helps PSTs recognize the lenses they bring to teaching, try on new ways of seeing (Irvine, 2003), and making sense of these moments with an understanding of why this is vital to the learning and growth of historically underserved students and families. Secondary goals of this work are to help teachers see what a critical stance (Caraballo, 2017)and forms of anti-oppressive education (Kumashiro, 2000) or critical pedagogy (Ellsworth, 1989) look like in practice and to recognize when their habitual ways of responding are not in line with more equitable ways of engaging with students, families, and coworkers. Simulations are used in courses that are a-disciplinary, looking at situations teachers may encounter across content areas, and in courses specific to a content area to consider how systems of oppression are tied up in particular disciplines, including math and science.

Theory of Action

Our theory of action is heavily situated in two philosophies of teaching and learning – first, Dewey's (1938/1997) ideas of experiential learning, in that the primary feature of teaching approximated is the way that the cognitive, behavioral, and affective come together in an experience to shape one's response. Second, Gadamer's (1960/2011) notions of being "pulled up short," in that we seek to cause PSTs to use these encounters as a critical incident that ground their concepts in both the general and particular moments being simulated. Broadly, the theory of action that underlies the SHIFT Project is that safe, supported opportunities to

make sense of moments of teaching in which teachers' and students' identities are implicated can serve to ground teachers' commitments to anti-oppressive education.

- By *safe, supported opportunities*, we mean outside of actual field experience such that both the PST and real students and families are safe from the consequences of PSTs' missteps, and PSTs are supported to make sense of their decision-making rather than simply evaluated. For this reason, we never use simulated encounters for assessment purposes. Moreover, the individual nature of the encounter paired with the shared nature of the group debrief means PSTs have all engaged in the encounter and the instructor has seen them, but PSTs do not have to make that public to their peers to be judged on it if they choose not to. The theory here is this makes PSTs accountable to what they actually did while minimizing their defensiveness when talking about issues of race, class, gender, etc.

- By *make sense of*, we mean engaging PSTs in a deliberate process to understand where their responses come from (in terms of things like Dewey's (1938/1997) unthinking habit, Kumashiro's (1999) citationality practices, Lortie's (1975) apprenticeship of observation) and with a vision for where they might lead. Rather than labeling PSTs responses as "good/bad," we help them see the many things that influence our individual responses to a scenario in order to recognize those that are connected to oppressive forces (eg. Whiteness) and consider how their responses might change if influenced by different commitments (eg. racial justice or equity). The theory here is that when PSTs see their responses as rational but within a given paradigm, they recognize their actions must shift if their paradigm or ideologies do, leading to a desire for change rather than an expectation of it.

- By *moments in which teachers' and students' identities are implicated*, we mean scenarios in which visible or invisible aspects of identity are raised in order to surface the question of how school (and) systems are designed with particular groups in mind. The encounters are highly contextual, specific even to temporal events and our geographic location, and teachers' and students' own personhood are sometimes questioned (ex. an undocumented students' ability to access education in a time of travel bans and ICE raids, a queer teacher being positioned by a student as a "sinner" in the conservative South). In this sense, there is not a high degree of fidelity in how we use simulations because the scenario itself necessarily changes based on who the actor is, who the PST is, and how they come to engage their identities (or not) in the encounter (all of which is interrogated in the group debrief). These aspects of the scenario are always embedded in more general moments of teaching in an effort to consider the affective aspects of teaching and to help teachers see that these concerns are always present, whether we recognize them or not. The theory here is that by blending these intentionally, PSTs recognize that any given scenario in teaching is always a matter of "what works" but "how and by/for whom."

- By *grounding commitments to anti-oppressive education*, we mean that simulations are used not to prepare PSTs with a set of core actions to use in scenarios like the ones being simulated, but to help PSTs see how particular actions would serve to either reinforce or disrupt existing systems of oppression at play in these scenarios (and beyond). The encounters are not the place of learning, but a tool leveraged to support learning. By helping PSTs see, for example, how their response to a scenario may ultimately disengage a reluctant learner, or even recognize that their response was productive in ways they did not realize, we set them up to keep issues of oppression always in view. We know that learning has occurred if PSTs, unprompted – begin to consider unintended consequences of their responses after the fact, recognize the ways in which their own positionality and that of the student were relevant within the given context, and seek out alternative approaches that align with liberatory and transformative notions of education (hooks, 1994), whether in future simulations or scenarios they experience in the field.

Learnings

Analyses of simulations in the SHIFT Project have primarily relied on critical discourse (Gee, 2011; Rogers, Malancharuvil-Berkes, Mosley, Hui, & Joseph, 2005) and interactional analysis (Tannen & Wallat, 1987) methods, often looking at group-level or case studies (Yin, 2009). Early analyses considered what PSTs thought they learned from a specific encounter, looking for patterns in teachers' perceptions or comparing different trajectories towards shared perceptions of what they learned (Self, 2016). Here, we attended to not whether teachers were learning what we hoped they would, but tried to understand what they thought they had learned, based on their ability to narrate their own learning. Moreover, we sought to examine the design of the early simulation cycle and at what point PSTs were "pulled up short" in the process. More recent analyses (currently in progress or forthcoming) have analyzed the complexity of particular scenarios, the role of artifacts in disciplinary-specific encounters, and the extent to which simulations can provide information about what PSTs find difficult in them, in order to provide subsequent learning opportunities that help them work through that difficulty in order to enact rigorous, ambitious, equitable pedagogies once in the classroom. Most of the analyses we have conducted or have in progress look at the data produced after the encounter (raw debrief, re-reading questions, group debrief), though some have used the full data set including the videos themselves. Two analyses in progress examines how the design or use of a particular scenario has iteratively evolved over time, based on what we saw as designers and instructors. This includes complete redesigns over three years, in the case of one course simulation, or the slow improvement over four years of the group debrief after another scenario that has otherwise not changed at all since its first use.

Future Directions

Our future work with the SHIFT Project focuses on several persistent questions:

- To what extent must the design of an encounter consider the range of teacher identities who will engage with it? To what extent does a failure to do so reify hegemonic forces like Whiteness, heternormativity, etc.?
- What principles should guide the supported learning that follows an encounter (raw debrief, re-reading questions, group debrief) in order to maximize student learning, while leaving space for what teachers bring to the experience?
- What components must exist in a course/program in order for simulations as we use them to be successful in building teachers up as anti-oppressive educators, and not just heightening their awareness of what might go wrong?
- What are the moral and ethical concerns of using live actor simulations? What are the moral and ethical concerns of using more flat representations (avatars, etc.)?

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Simulated Student Interviews for Preservice Elementary Science Teaching

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Keywords: science education, teacher preparation, approximation, assessment, live simulation

Project Overview

One emerging approach for gauging and supporting beginning teachers' abilities is simulated interaction pedagogy. Similar to simulated patient interviews in medicine, this approach involves a preservice teacher interacting with an individual following a standardized protocol around a particular set of skills. Our project considers the potential of using this type of simulated student interview, focused on preservice elementary teachers' practices and knowledge for science teaching, to provide feedback to teacher educators and the teachers themselves. In particular, we investigate a simulated student interview we designed to characterize preservice elementary teachers' abilities to engage students in *analyzing data* and *constructing evidence-based claims in science*, two high-leverage science teaching practices, and their associated science knowledge for teaching. The simulated student interview is used as an assessment in the elementary teacher education program for undergraduate students.

The designed simulated student interaction involves teachers engaging with an adult acting as an upper elementary student in analyzing data and constructing an evidence-based claim regarding the conservation of mass. This "simulated student" has a protocol of behaviors, responses, and lines of thought to use in interacting with the preservice teachers. This protocol also includes a set of potential triggers with particular responses for the simulated student. Prior to the interaction, teachers receive information about an elementary class' investigation, the learning objective for the interaction, and prior knowledge discussed in the class. Focused on the big idea of conservation of mass, the investigation is centered on the question "how does the weight of a salt water solution compare to the weight of the materials used to make up the solution?" We also provide three example student predictions and data collected by three "student groups" during the investigation. First, each teacher plans how she would support a student to make sense of the data to answer the investigation question. Then, she works with the "simulated student" to analyze the data and construct an evidence-based claim. She can ask questions, write representations, and have the student write down their thoughts. Questions about the teaching moves made and the rationale for their choices follow the interaction.

Theory of Action

Features of teaching. The simulated interaction focuses on two high-leverage science teaching practices: *engaging students in analyzing data* and suppor*ting students in constructing evidence-based claims*. In the simulated interaction, the "teacher" is working one-on-one with a

"student" who is struggling to see how the data collected in an investigation (described in the written packet) demonstrates the idea of conservation of mass. The main emphasis in the interaction is on how the teacher organizes and represents three groups' data from the investigation to allow the student to see patterns in the data. As the interaction unfolds, we also see if the teacher thinks to return to the investigation question to make a claim supported by evidence. Thus, three key features of teaching are approximated: these two high-leverage science teaching practices as well as the teacher's content knowledge for teaching (primarily, their own subject-matter understanding of the concept of conservation of mass). Given that the simulation involves only a single "student", the simulation has some fidelity to working with an individual student but not with a whole class. That said, with regard to the simulation's emphasis on data representation and analysis, the fidelity is relatively high, because of the parallels between how this work would be done with an individual or with a whole class.

Actors, roles, and context. The simulation involves two actors: the preservice teacher and the teacher educator. The preservice teacher plays the role of the teacher. The teacher educator plays two roles: initially, they serve as the simulated student, and later in the interaction, they play the role of interviewer. We attend to context by providing written materials that describe some of what the "class" has studied previously and give sample student work from three "groups." We do not, in the current instantiation of the simulation, attend to other key aspects of context that a teacher would need to attend to in reality, such as the demographic make-up of the school and community, the student's own language and cultural background, the student's experiences with science learning, and other dimensions that inform teachers' interactions with children. This is a limitation of this version.

Expected learning and assessment. This simulation is not aimed at teacher learning, but rather, serves as a pre-assessment to give us insight into preservice teachers' strengths and struggles with the two high-leverage science teaching practices and their content knowledge for teaching science. We do, however, see the experiences of trying out teaching moves and reflecting on teaching during the simulation and following interview as opportunities for growth. Specifically, preservice teachers may develop a better understanding of how elementary students might react to particular teaching moves and greater capacity to reflect on their own science knowledge for teaching and their teaching practices, as a result of participating in the simulation. We have also used the simulation in research and teaching to see changes in preservice teachers' learning by comparing preservice teachers' interactions and responses in the simulations before and after learning about analyzing data and constructing evidence-based claims during a science methods course (Arias, 2015; Arias & Davis, 2017).

Learnings

To consider the potential of this simulation, we conducted a study of 22 preservice teachers engaging in the simulated student interviews. Six of the preservice teachers served as focal

participants. In this study, the preservice teachers showed strengths like creating clear representations and areas for improvement like using sufficient evidence for a claim. The simulated student interviews allowed for different elements of science teaching to be seen when compared to lesson plans, including the teachers' engagement of students in the intellectual work. For brevity, we focus here only on the simulated interactions, not on the comparisons between the lesson plans and the simulated interactions. Table 1 summarizes the focal preservice teachers' engagement in the two high-leverage science teaching practices as well as their demonstrated content knowledge for teaching science.

In sum, the simulated student interactions showed areas of variation and commonality in the preservice teachers' abilities and knowledge around using representations to analyze data and supporting students in constructing evidence-based claims, at one particular point in a practice-based teacher education program. These variations and commonalities were not unexpected given the preservice teachers' prior experiences within and outside of the teacher education program (e.g., Anderson, Smith, & Peasley, 2000; Stroupe, 2014). However, a close examination of the preservice teachers' abilities and knowledge provides insights about how to build on preservice teachers' strengths and support these teachers in their struggles as well as the complexity of learning to teach elementary science.

In terms of *supporting students in analyzing data*, the preservice teachers showed strengths in selecting, developing, and using appropriate representations that support an elementary student to analyze and interpret data. However, the preservice teachers tended to struggle with developing representations of the data that would include all of the multiple data sources. This struggle in analyzing and interpreting all relevant data is similar to the struggles seen with secondary teachers and K-12 students (e.g., Wu & Krajcik, 2006), suggesting that these learners and teachers might benefit from additional focus on the development of representations of collected data.

Table 1: Summary of focal teachers' interactions across teaching practices and science knowledge for teaching.

Student Name	Using Representations to Analyze Data	Constructing Evidence-Based Claims	Science Knowledge of Teaching
Ashley	*Partially meets* Created a picture to analyze data, yet representation was difficult to follow at a later time. Involved student in creation of representation.	*Partially meets* Guided the student to make an accurate claim, yet told the student the answer at beginning of the interaction.	*Partially meets* Described science content accurately but did not discuss conservation of mass.
Diana	*Does not meet* Created a picture to analyze data, yet representation was difficult to follow at a later time. Did not involve student in creation.	*Partially meets* Developed an accurate claim with the student that answered the investigation question. Drew on data from one group.	*Does not meet* Inaccurately described dissolving salt as changing state and did not discuss conservation of mass.
Ginny	*Partially meets* Finished creating a table with the student including data from two groups, yet representation was difficult to follow at a later time.	*Meets expectations* Generated with the student an accurate claim that would answer the investigation question. Drew on two groups' data and discussed mechanism.	*Meets expectations* Described science content accurately. Discussed the mechanism and conservation of mass.
Kelly	*Partially meets* Created a labeled picture with the student that would answer investigation question. Included one group's data.	*Partially meets* Developed an accurate claim with student that answers investigation question based on one group's data.	*Partially meets* Described science content accurately but did not discuss conservation of mass.
Na'ilah	*Does not meet* Used the table found in the original packet. Seemed to become confused during the interaction.	*Does not meet* Accepted an inaccurate claim as accurate.	*Does not meet* Accepted an inaccurate claim as accurate.

Student Name	Using Representations to Analyze Data	Constructing Evidence-Based Claims	Science Knowledge of Teaching
Terri	*Meets expectations* Used a well-labeled table that would answer investigation question with data from all three groups. Wrote information provided by the student.	*Meets expectations* Generated with the student an accurate claim that would answer the investigation question and drew on data from all three groups.	*Does not meet* Discussed that you could see dissolved salt under the magnifying glass, which is inaccurate.

In terms of the preservice teachers' ability to *support students to construct evidence-based claims*, the preservice teachers commonly connected their claims to evidence collected during an investigation. However, the preservice teachers did not always use sufficient evidence to support their claims. They also struggled to support to students in reasoning about how and why the evidence connects to the claims. Other studies have found similar strengths and struggles in preservice teachers' abilities to engage in constructing evidence-based claims (e.g., Haefner & Zembal-Saul, 2004; Zangori & Forbes, 2013). These findings imply that teacher educators might build on the preservice teachers' tendency to use evidence to facilitate the teachers in learning how to support the reasoning involved in scientific argumentation and explanation.

In their *science knowledge for teaching*, the preservice teachers typically struggled to describe the connection to conservation of mass. In addition, some preservice teachers struggled with explaining the scientific phenomenon of dissolving salt. These findings are not unexpected given the studies that have discussed elementary teachers' struggles with science content knowledge and pedagogical content knowledge (e.g., Van Driel et al., 2014). In contrast, the preservice teachers typically used accurate scientific language and identified appropriate areas of revision and strength after the interactions.

One key learning is that the simulation does allow us to untangle closely-related high-leverage science teaching practices (supporting students in representing and analyzing data and constructing evidence-based claims), *and* that preservice teachers' performances on these high-leverage science teaching practices were variable. While most preservice teachers partially met expectations for each of the three dimensions we looked at – a not surprising finding given that this simulation serves as a pre-assessment prior to the science methods course – only four of the 22 preservice teachers were consistent across all three dimensions in partially meeting expectations. In other words, the simulated interaction allows us to characterize an aspect of the complexity of teaching and learning to teach.

Future Directions

We face a number of conceptual and practical challenges in this work. Some of the conceptual challenges, which serve as directions for our future work, include balancing between using the simulations as a learning experience and as an assessment; making valid characterizations of preservice teachers' performance in the simulated assessment; ensuring the simulations provide a meaningful representation of elementary science teaching within a controlled environment; developing conceptual tasks in elementary science on which to work in the simulations; and characterizing the consistency between written plans for the simulated interaction versus the enactment of the simulation itself. We also hope to learn from others to gain traction on some of the more pragmatic challenges we face, including training interviewers in enacting the simulated interview protocol; ensuring consistency across interviewers; and managing the logistics of running 30-50 interviews in a timely manner.

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Simulations as Professional Apprenticeships

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Keywords: teacher preparation, rehearsals, approximation, assessment, digital/live simulation

Project Overview

Teaching is a complex profession that demands significant content knowledge and social competence; however, educator preparation programs tend to focus more on developing novices' knowledge and less on fostering their ability to *use their knowledge fluently* in the social context of schools. This uneven attention is particularly visible around teacher candidates' preparation for family engagement. Every year, three million teachers sit down with ~90 million families to discuss students' academic progress. Yet, most new teachers are denied opportunities to learn about how to conduct these complex conversations (Epstein & Sanders 2006). It is no wonder then that teachers and families alike express dissatisfaction with their interactions (Hoover-Dempsey et al., 2002; Lawrence-Lightfoot 2004; Markow & Pieters 2012). Feelings of dissatisfaction matter because teacher-family interactions influence student learning and classroom experiences even in the earliest years of school (Dearing et al., 2006; Kraft & Dougherty, 2013; Wyrick & Rudasill, 2009).

For decades, scholars have called for educator preparation programs to improve teacher preparation by adopting pedagogies that situate the knowledge of teaching in the social realities of teachers' day-to-day work (e.g., Shulman, 1992). I hope the SITE conference can move the needle on this call by fostering a common language and collective activity amongst teacher educators who use situated pedagogies as part of candidates' professional apprenticeship. Teacher educators who use situated pedagogies to integrate the social and cognitive demands of teaching must overcome two primary challenges. Practically, simulations, must fit into an already crowded and regulated curriculum. Second, because the professional social interactions that candidates need to experience before they enter the field are often sensitive and complex, they must be carefully modeled and scaffolded. Flexible, user-friendly and high-quality simulations are essential.

For me, a simulation is a tool that allows learners to *experience* a real-world professional task rather than being told about it. In my teaching and research, I have developed two kinds of simulations: (1) digital case studies depicting challenges in parent-teacher conference communication, which allow candidates to examine representations of practice and (2) embodied real-time parent-teacher conferences, or standardized simulations, which allow for enacting approximations of practice. (A standardized simulation involves having a candidate directly engage with an actor who plays the parental role and is trained to present a consistent set of conversational challenges; see Dotger et al., 2011 for procedural details). My specific aims in using these simulations has been to develop candidates' knowledge and flexible use of

student assessment data, and their readiness for family engagement. Digital cases leverage vicarious experience; standardized simulations use direct experience.

My instructional efforts align with other efforts to integrate the social and cognitive demands of teaching, such as ambitious teaching (Lampert et al., 2013). At the heart of ambitious teaching is instructional dialogue or *the ability to co-construct a conversation in the moment in response to students and content*. By extension, I prepare candidates to co-construct conversations about student content learning in response to family and student circumstances. Further, my instructional use of vicarious and direct simulations to enhance candidates' professional readiness is consistent with ambitious teaching's general design principles—nested, sequential models of increasing complexity, frequent assessment, and decreasing scaffolding as task authenticity increases.

For example, when designing a six-week unit on assessment in undergraduate and graduate educational psychology courses, I assumed that situating rather abstract assessment concepts (e.g., validity, reliability, standardization, norming, etc.) in the authentic social context of parent-teacher interactions would make it more memorable and relevant while also underscoring teaching's intertwined cognitive and social demands. The unit began with traditional, instructor-facilitated case-based instruction. Cases focused on the common dilemma of homework 'compliance,' how to respond to parents' questions about report card grades, and on determining and communicating criteria for selecting students for a gifted and talented program. Candidates then engaged with three digital cases centered on challenges including sharing difficult news about students' academic performance and responding to parental challenges to teacher academic expectations. In the unit's summative assessment, candidates engaged in two standardized simulations. In each, they were responsible for (a) accurately analyzing and interpreting a set of assessment artifacts and then (b) explaining their understanding of the student, the assessments, their results, and their implications to the student's mother. In total, candidates experienced seven different professional situations that involved assessment and family engagement. Across the unit, candidates received direct instruction and feedback on other traditional assessments of their learning (e.g., quizzes, homework).

From a research standpoint, my overarching goals are to understand the affordances and constraints of vicarious and direct simulations, their psychological 'active ingredients' and their impact on candidate knowledge, skills and dispositions. I am also curious about how the sequencing of vicarious and direct learning experiences impacts learning and engagement. My applied goals include supporting teacher educators' capacity to design and use authentic, valid and reliable simulations.

Theory of Action and Approximation Models

In professional education, experiential learning is often conceived of as apprenticeship. In traditional apprenticeship, novices gradually master and independently perform higher-level challenges through direct instruction, observation and practice (Lave & Wenger 1999). This approach is limited, however, because it relies on naturally occurring events; when critical events occur infrequently, learning is slowed. If important challenges are never experienced, then uneven skills and knowledge can develop.

The affordances of simulations compensate for these limitations. First, simulations are customizable; instructors can ensure that critical and common events are experienced. Second, they allow for deliberate practice of specific skills at varying levels of intensity and complexity (Ericsson 2006). Third, simulations are ethical; they allow learners to experience authentic challenges, make choices and take risks without harm to themselves or others. Finally, unlike the real world, simulations provide opportunities for 'do-overs.' Instructors can intervene to offer feedback that novices can use to immediately improve their performance. These features make simulations an essential and complementary form of professional apprenticeship.

The vicarious and direct simulations target the same outcomes: (1) effective parent-teacher conference communication practices and (2) accurate knowledge and flexible use of student assessment data. To teach and assess the first target, I use Walker and Dotger's (2012) Framework of Effective Parent-Teacher Conferences (PTC), which argues that an effective PTC is both structured and responsive. The structuring dimension offers novices a conversational script for how to initiate, develop and conclude any PTC. Specific aspects include: opening the conference by thanking parents for their time and clearly stating the conversation's goals for the student; developing a dialogue by sharing and gathering information; and closing with the development of a collaborative action plan that spells out the individual and shared responsibilities of teacher, parent and student. This sequence is orchestrated by attention to managing flow, which involves monitoring time constraints and ensuring that the conversation involves give-and-take. The responsive dimension involves two aspects: empathy or looking at the situation from the student and family perspective and maintaining positive expectations or keeping the conversation focused on the student's well-being and academic progress.

Because the Framework of Effective PTCs was derived from a study of expertise, I expect that if candidates develop proficiency at its specific aspects, they will avoid common errors of practice. For example, while parents want teachers who invite and value their knowledge about how their children learn and behave (Green et al., 2007; Lawrence-Lightfoot 2004), they often describe parent-teacher conferences as "meetings without dialogue" (Guo 2010; Pruitt et al., 1998). For their part, teachers equate "meeting with parents" with "addressing problems" (Denessen et al., 2009; Lawrence-Lightfoot, 2004), which may explain why many regard family

engagement as one of the most challenging aspects of their work (Hoover-Dempsey et al., 2002; Markow & Pieters 2012).

To assess the second target, accurate knowledge and flexible use of student assessment data, I evaluate the accuracy of candidates' analysis, interpretation and response to the assessment artifacts or profiles they are given. I also standardize the live simulations in ways that present each candidate with the same questions and challenges that parents can present when discussing their children's learning (e.g., Are you sure? How do you know? What does that mean?). I evaluate candidates' responses to these standardized prompts in real-time using a scoring rubric. To date, I have not evaluated candidates' assessment knowledge in the digital cases. Rather, I use them to introduce candidates to various representations of practice and then how those representations can be decomposed into the Framework of Effective PTCs.

The vicarious and direct simulations follow a common set of basic psychological structures: (1) eliciting prior knowledge, skills and dispositions, (2) modeling problem-scoping and problem-solving strategies, and (3) prompting revision and goal setting. Below I describe each 'use case' in more detail.

Sequence and Processes in Digital Cases

To begin a case, candidates read a teacher-student history, written from the teacher's point of view, which culminates in a decision point. They are asked, "If you were the teacher, what would you do?" This phase elicits prior knowledge, skills and dispositions. Psychologically, it also leverages candidates' capacity for Theory of Mind (ToM) or perspective-taking, which is crucial for everyday interactions, cooperation, and learning. Fortunately, perspective-taking is malleable and simulated action is an effective means of developing it (Goldstein & Winner 2012).

Next, candidates watch two videos, each one depicting how a different teacher/model approached the case challenge. Vivid representations of practice, like video models, build schema in visual memory (Sherin & Van Es, 2005) and are essential to future learning because they shape what we notice, what we infer from what we see, and how we use those observations and inferences to gain traction on a problem (Kolb, 2014). As they view the videos, candidates are prompted to evaluate each model's performance. The models depict carefully constructed contrasts (e.g., one is structured but not responsive, the other is the opposite). An example of the kinds of videos that candidates view can be seen here: http://www.caepfamilyengagement.org.

To underscore the consequences of the models' actions and promote vicarious reinforcement (Bandura, 1997), candidates then view a brief video in which the parent in the simulation describes her conference experience. Finally, candidates see how experts would approach the

case and are asked to review their initial ideas and make revisions in light of any new understandings.

Comparing the models, hearing the parent's perspective and then comparing their own initial ideas to those of experts incites the disequilibrium needed to foster adaptation of knowledge, skills and dispositions. The difference between their initial and revised ideas is used as an indicator of learning.

Sequence and Processes in Standardized Simulations

In standardized simulations, rather than observing others' actions, candidates become the actor. In the Plan phase, candidates analyze the case materials and prepare a plan for their meeting with the family using the Framework for Effective PTCs as a guide. Next, candidates enact their plan in real time. What transpires is the result of their individual moves in response to emergent elements of the simulation environment. Candidates must continuously integrate new events into prior knowledge and (re)construct their understanding, which fosters fluent retrieval and flexible use of prior knowledge (Ericsson, 2006). Inevitably, standardized simulations do not go as planned, which habituates candidates to encountering uncertainty and the fact that teaching is often improvisation. Experiencing disequilibrium also arouses emotions that foster deep learning (D'Mello & Graesser 2011). In this way, standardized simulations are most consistent with the concept of experiential learning (Kolb, 1984) and Dewey's (2007) conception of an *interactive* and *continuous* educational situation. In addition to feedback from their conversational partner, candidates receive instructor feedback via debriefing conversations immediately after each simulation. The final source of feedback is retrospective; candidates reflect on a video recording of their performance. To maximize learning, candidates are asked to set specific professional development goals based on their simulation experiences. Reflection allows candidates to examine the limits of their current knowledge, skills and dispositions and how they intersect with their ability to successfully perform a professional task. As with the digital cases, similarities and differences between candidates intended plans and actions and their actual simulation behavior is used as an indicator of learning about family engagement.

Learnings

Candidates' ability to recognize and use the seven aspects within the Framework of Effective PTCs has been reliably assessed across the digital cases and standardized simulations (e.g., Walker & Dotger, 2012; Walker & Legg, 2018; Walker & Marksbury, 2015).

Digital Cases

Candidates can accurately detect the models' contrasting actions, which supports their content validity. Analysis of candidates' initial plans for one case exemplify their readiness for family engagement. First, few candidates note the importance of the *opening*. Instead, consistent with

evidence that teachers tend to talk *at* rather than *with* families, most candidates plunge into *sharing information* and *taking action*. To their credit, nearly all candidates *gather information*, yet they tend to pose basic questions (e.g., "Has anything like this happened before?"). Few candidates ask student-centered question (e.g., "Is he engaged in any after-school activities?") or ask questions that leverage the family's expertise (e.g., "How do you keep him focused and attentive?"). Finally, few candidates note the importance of empathy. After completing the case, their revised plans showed much greater attention to clearly framing a purpose for the meeting during the opening; however, their attention to taking the parent's perspective did not increase significantly.

Standardized Simulations

Standardized simulations reveal substantial variability in candidate performance and personalized points of entry for advancing each candidate's professional development (Pankowski & Walker, 2016; Walker & Legg, 2018). Candidates' reflections provide a window into their struggle to accurately and responsively share information about student learning within a structured time frame, e.g., 'It was hard to walk the line between empathy and taking control' and 'I need to ask questions before making suggestions and avoid using jargon.' Across reflections, the probabilistic quality of their experience is also evident, e.g., 'Be prepared for anything' and 'Have a Plan B. And a Plan C.'

What I find interesting about both simulation tasks are candidates' reactions to them. Several have asked if I have more cases they can watch or if they can try another standardized simulation. I've never had a candidate ask that about any other course assignment.

Future Directions

Whether on my own or as part of a collective, I would like to pursue any of the following questions:

1. How real does it have to be? What level of immersion and personalization are required to advance learning? These questions are central to fostering adoption of situated pedagogies at scale. They are also central to issues of equity; all preparation programs should have access to the best teaching tools available, even if some can afford more 'bells and whistles.'
2. What's a sufficient dosage, to learn what and for whom? How much exposure to various kinds of simulations are required to advance candidates' professional knowledge, skills and dispositions?
3. How do we know if simulations are having an effect? And what are they effecting? Identity? Efficacy? Implicit bias? Because simulations are designed environments, we have rich opportunities to explore ethically charged issues that are otherwise impossible in traditional educational research settings.

4. Do simulations increase candidate workplace readiness? Short- and long-term transfer studies are essential. The problem of "inert knowledge" is longstanding; few systematic efforts to address it have surfaced.

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