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Science Teacher Candidates' Questioning and Discussion Skill Performance in a Virtual Simulation Using Experiential Deliberate Practice

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ABSTRACT

Effective questioning and discussion are fundamental instructional skills for science teacher candidates to master. These skills are important for teacher competence that aids student achievement. Opportunities to practice these skills in traditional teacher preparation programs may be limited. This embedded single case study focused on an intervention consisting of an experiential deliberate practice approach which provides a virtual learning simulation experience and asynchronous skill development provided science teacher candidates with the opportunity to learn and practice questioning and discussion skills. Teacher candidates taught the same lesson three times to avatars over the course of three weeks to establish a baseline and post-intervention practices. Feedback was provided after each teaching experience and asynchronous skill development modules were presented between each teaching session. Data included scores of teacher practice using an evaluation rubric for questioning and facilitating discussions, self-reflective surveys after each teaching session, and culminating semi-structured interviews. Both participant self-reporting through surveys and interviews and scorer ratings of lessons supported the intervention having positive impacts on skill competencies of participants.

KEYWORDS

Deliberate practice;
experiential learning; field
experience; questioning and
discussion; simulation

Introduction

Many science teachers enter the classroom underprepared to ask effective questions and facilitate productive class discussions (Levine, 2006; Oliveira, 2010), which has been linked to high novice teacher turnover (Helms-Lorenz et al., 2016; Karbownik, 2014), especially in Science, Technology, Engineering, and Mathematics (STEM) programs (Carver-Thomas & Darling-Hammond, 2017; Dee & Goldhaber, 2017; Hansen et al., 2019). Teacher attrition is a serious detriment to students and their learning. Turnover during the school year can lead to disruptions in student learning, teacher quality, and student achievement (Henry & Redding, 2020). Thoughtfully structured virtual practice or scenario-based learning opportunities that develop fundamental teaching skills may aid in preparing science teacher candidates prior to classroom teaching experiences (Klassen et al., 2021) and therefore aid in mitigating factors that contribute to the attrition of science teachers (Helms-Lorenz et al., 2016; Karbownik, 2014).

Changes in teacher preparation

In 2010 the National Council for Accreditation of Teacher Education (NCATE) stated the “education of teachers needs to be turned upside down” (p. ii). NCATE called for a clinically based curriculum which ended the fragmentation of theory, knowledge, and practice in the classroom, arguing that the content of teacher preparation should be interwoven with clinical practice (p. ii). Clinical practice provides opportunities for prospective teachers to practice skills. Based on the proposals from NCATE, pre-service classes should move away from lecture and toward increased practicum experiences that allow teacher candidates to practice fundamental skills.

National Council for Accreditation of Teacher Education’s [NCATE’s] (2010) call for a clinical approach to developing teacher candidates have resulted in sustained efforts by scholars and policymakers to shift teacher preparation from knowledge acquisition to applied knowledge or practice-based activities (Walkoe & Levin, 2018). Some preparation programs have simultaneously transitioned to offering teacher education through online learning environments (DeMonte & Coggs, 2018). However, these online environments may not offer adequate opportunities for experience and genuine skill practice, thus limiting undergraduate science teacher candidates’ opportunities to practice fundamental teaching skills (Sezer et al., 2017). Furthermore, newly hired teachers educated in formal preparation programs were underprepared for the rigors of teaching due to a lack of significant practical experiences (Chesley & Jordan, 2012; Ellis et al., 2008; Kihara et al., 2009; Levine, 2006).

Despite the need for shifts in teacher preparation programs, only modest changes have been made at the local or national level (Cochran-Smith et al., 2016; Klette et al., 2017; Walkoe & Levin, 2018). Additionally, McDonald et al. (2014) demonstrated that teacher candidates in the United States and internationally benefit from engaging in practice opportunities, which they refer to as “mediated field placements” (p. 507) that enable teacher educators to provide “guided opportunities” (p. 507) that include feedback. Similarly, Davis et al. (2017) overviewed the positive impact of rehearsal and feedback for developing skills. Technology can be used to overcome limitations for practice, thus engaging science teacher candidates in interactive scenarios focused on skill development (Klassen et al., 2021).

Effective online practice

Opportunities for effective practice combine best practices from skill acquisition with science teacher preparation in online and virtual environments. One of the foundational studies in skill acquisition completed by Snoddy (1926) discovered that skill development is a function of skill practice time (Kaufman, 2013; Newell & Rosenbloom, 1981). When practice time is distributed among more days, the skill development increases exponentially. The more time a person practices, the more effective they become at the skill. Ericsson and colleagues demonstrated that time engaged in practice is a positive predictor of skill acquisition (Ericsson & Harwell, 2019; Ericsson et al., 1993; Ericsson & Pool, 2016).

However, not all approaches to practice are equal in effectiveness (Ericsson & Harwell, 2019). Research has demonstrated that time engaged in practice does not always guarantee skill development and expertise (Ericsson & Pool, 2016). Ericsson and Harwell (2019) assert that expertise will be most likely gained by engaging learners in repeated, deliberate

practice. In scenario-based learning and practice, Klassen et al. (2021) found that teacher candidates perceived and actual improvements were impacted by practice coupled with feedback and self-reflection.

In online environments, teacher educators struggle with providing critical practice experiences (Jiminez et al., 2016; Sezer et al., 2017). The potential for these practice opportunities has recently been demonstrated by the introduction of simulation technologies in teacher education (Gul & Pecore, 2020). Mixed-reality simulation technology uses avatars with digital characters and a human as a digital manipulator to blend virtual and real-life surroundings. Mixed-reality spaces have been shown to create authentic experiences (Gallegos, 2016; Gul & Pecore, 2020), provide intensive rehearsal (Judge et al., 2013), and offer retrieval and adjustment opportunities (Dieker et al., 2014).

Two online platforms available for creating a mixed-reality simulation online practice environment for teacher candidates are CanvasTM and MursionTM. CanvasTM is an online asynchronous tool that engages teacher candidates in fundamental aspects of learning and reflection. In this study, CanvasTM was used to deliver instruction on questioning and discussion techniques and strategies. CanvasTM learning modules included selected readings, videos, discussion boards, and student generated videos of questions. MursionTM is an online synchronous tool that provides a mixed-reality simulation for teacher candidates to practice and reflect. In this study, MursionTM was used to provide a teach-to-avatar experience where teacher candidates could teach a lesson to avatar students. The avatar students, controlled by a single human simulation specialist in real time, respond to the teacher candidates.

Questioning and discussion in science instruction

As questions and argumentation have been re-emphasized in the Science and Engineering Practices contained in the Next Generation Science Standards (NGSS Lead States, 2013) and similar state science standards, science teachers must be able to model and scaffold questioning that leads to authentic discussion between students. An essential feature of science teacher preparation is equipping prospective teachers with the necessary skills to succeed in their first year of teaching, including questioning and discussion skills (Ball & Forzani, 2009; Cumhur & Matteson, 2017; Grossman et al., 2009; Karsenti & Collin, 2011; NGSS Lead States, 2013). Teacher questioning and discussion skills can be developed through experiential deliberative practice, feedback, and instruction (Ericsson et al., 1993; Ericsson & Pool, 2016; Kolb, 1984; NGSS Lead States, 2013) and measured using the Danielson (2013) Framework for Domain 3b.

Questioning is an instructional strategy that can be effective in promoting student thinking across disciplines and grade levels (Cumhur & Matteson, 2017). Developing questioning strategies requires experience and practice which is traditionally facilitated through internship or student teaching experiences (Cumhur & Matteson, 2017; Robitaille & Maldonado, 2015). While questioning strategies may be developed through in-person experience, Klassen et al. (2021) reported the potential of online scenario-based learning to improve teacher candidate engagement and retention of skills.

Effective questioning can progress from surface-level checks for understanding to prompts that encourage student construction of knowledge through creating connections, making predictions, and revising prior knowledge. (Chen et al., 2017; Cumhur & Matteson,

2017; Kiemer et al., 2015; Robitaille & Maldonado, 2015). In addition, types of questions, the timing of questions, and the purpose of questions can lead to changes in student engagement and to increased discourse between students (Kiemer et al., 2015; Robitaille & Maldonado, 2015). Teacher proficiency with varied approaches to questioning can aid in fostering discussion between teacher and students as well as between students, thus connecting the effectiveness of questioning with facilitating discussions (Chen et al., 2017; Cumhur & Matteson, 2017; McCarthy et al., 2016). Furthermore, science teacher candidates can use questioning techniques to engage students in a discussion, build on student questions and answers, aid students in explaining their thinking, and support students in justifying answers or positions with valid and reliable evidence. Thus, questioning can build engaging discussions that develop language and conceptual understanding (Danielson, 2013; NGSS Lead States, 2013).

Theoretical framework

Most previous skill-based research using simulations occurs in conjunction with a face-to-face class (Hardin & Freeman-Green, 2015; Lee et al., 2018; Mikeska et al., 2019; Piro & O'Callaghan, 2019). Sasaki et al. (2020) explored an online approach; however, their study provided feedback on simulated practices a week after performance. Since the feedback was not more immediate, the study was not aligned with skill development theory (Ericsson & Harwell, 2019; Klassen et al., 2021).

Deliberate practice is a skill development theory that occurs under the direction of an expert mentor who assesses the participant and assigns individualized skill practice sessions distributed over time. Practice sessions are deliberately designed to 1) push participants past their comfort zones, 2) provide immediate and timely feedback for improvement, 3) offer opportunities to implement feedback, 4) evaluate performance on a standard, and 5) develop expert skills (Ericsson & Harwell, 2019). Most research has focused on experts and not novices where deliberate practice is estimated to account for more than half the variance in expert performance (Ericsson & Harwell, 2019). While few studies have applied deliberate practice theory to teacher preparation, those that do lack important key criteria of deliberate practice (Ericsson & Harwell, 2019).

Kolb's (1984) experiential learning is a four-stage cycle which begins at any step but proceeds in logical sequential order. The learner has a concrete experience, participates in reflective observation on the experience, forms abstract conceptualization (analysis and conclusions), and then applies active experimentation resulting in new experiences (Kolb, 1984). Effective learning only occurs when a learner can execute all four stages of the model. Since adult learners typically begin with concrete experiences, teaching experiences such as practice of skills focused on questioning and facilitating discussion, can engage science teacher candidates prior to receiving expert feedback and reflecting on their practice (Klassen et al., 2021; Kolb, 1984). Learning can lead to concrete experiences that engage teacher candidates in cycles of experiential learning with improved skills (Kolb, 1984).

The theoretical framework for this study as shown in Figure 1 combines deliberate practice with experiential learning theory. Figure 1 was created by the authors to illustrate how deliberate practice was embedded in experiential learning (Ericsson et al., 1993; Kolb, 1984). Kolb's (1984) experiential learning theory described how knowledge results from combining grasping and transforming experiences. Knowledge is thus created through the

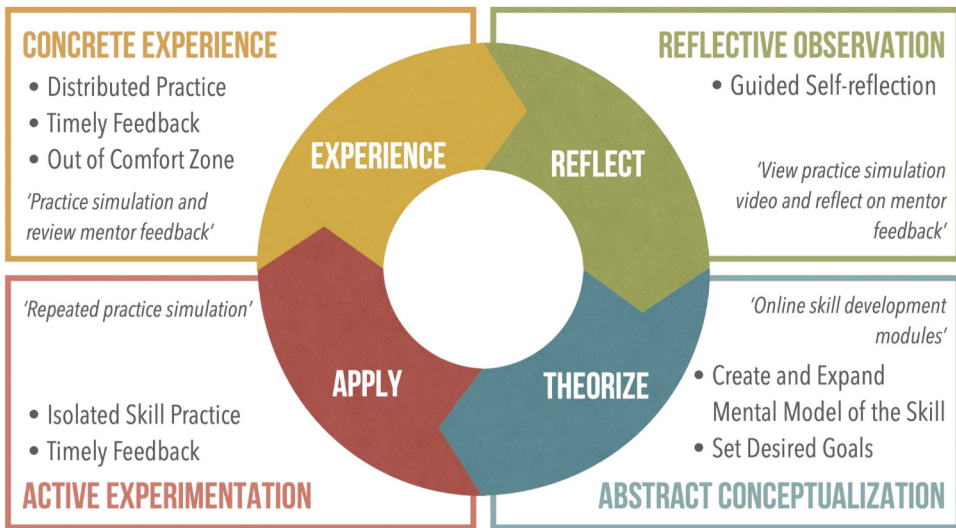


Figure 1. Experiential deliberate practice. Figure 1 depicts Ericsson et al.'s (1993) deliberate practice theory (bulleted components) mapped onto Kolb's (1984) experiential learning cycle components (bolded headings) as the theoretical framework for this study.

transformation of experience in a holistic approach emphasizing how experiences (cognitions, environmental factors, and emotions) influence the learning process. Grasping involves concrete experiences serving as a basis for reflection and abstract conceptualizations formed from assimilating the information after reflection. Transforming encompasses reflection on experiences for drawing new implications which can be actively tested and guided by creating new experiences (Kolb et al., 2000). Kolb's (1984) experiential learning cycle can be experienced by science teacher candidates within deliberate practice (Ericsson & Harwell, 2019).

A large obstacle to practice-based teacher preparation is the lack of instructional activities and pedagogies (Peercy & Troyan, 2017). The challenge of providing access to opportunities for repeated practice in a traditional setting limits teacher candidate engagement in the experiential learning cycle (Ericsson & Harwell, 2019; Kolb, 1984). However, deliberate practice in a virtual environment provides a promising approach to address these challenges and bridge experiential learning and deliberate practice (Ericsson & Harwell, 2019; Kolb, 1984; Kolb et al., 2000).

Research question

This research addresses the gap in understanding of the use of virtual mixed reality simulations with experiential learning and deliberate practice as a means for improving teacher candidates' competencies (Ericsson & Harwell, 2019; Klassen et al., 2021; Kolb, 1984; Kolb et al., 2000). This research study investigates science teacher candidates' skills in questioning and facilitating discussions to address the question: How are undergraduate science teacher candidates' performance ratings and self-perceptions of questioning and discussion skills impacted by online experiential deliberate practice?

Methods

An embedded single case study research design was used to explore the use of deliberate experiential practice to impact science teacher candidate skills in questioning and discussion for this study (Yin, 2017). Six science teacher candidates' actions and perceptions during a three-week simulation experience represent the phenomenon for this qualitative case study. Data were gathered on science teacher candidates' practices of implementing questioning and discussion skills learned in a virtual format. Learning was facilitated using both CanvasTM and MursionTM platforms. Science teacher candidates' instruction and reflection were data for describing teacher actions related to questioning and discussion techniques (Stake, 1995; Yin, 2017). This research was approved by the Institutional Review Board for the Protection of Human Research Participants (IRB) project titled "IRB 2020–227, Online Deliberate Practice of Questioning and Discussion Skills: A Pilot Study" at a public university in the southeastern United States.

Participants

Participants were six science teacher candidates enrolled in a public university in the southeast United States. The participants represent a convenience sample recruited from an undergraduate secondary science methods course. Three participants identified as male and three identified as female. Two participants identified as underrepresented minorities. Participants volunteered to complete the experience, which preceded student teaching experiences for all participants.

Study context

Participants in this study were recruited from a secondary science methods course to provide a supplementary optional learning experience within the course. Participants engaged in the teach-to-avatar project beginning in week nine of a 16-week semester moving through the orientation, three synchronous simulation experiences teaching the water cycle, and continuous asynchronous instruction through learning modules. There was no explicit instruction on questioning and discussion skills prior to participation in the teach-to-avatar experience. As shown in the timeline in [Figure 2](#), surveys were completed after each teaching session, feedback was given by an expert teacher, and asynchronous instruction between each simulation was provided using learning modules. A final semi-structured interview was completed with each participant at the end of the experience.

Lesson scenario on the water cycle

Participants engaged in a 10–15-minute teaching segment on the water cycle (Bielke et al., 2017) using the MursionTM online platform. A water cycle scenario provided to participants, developed by Bielke et al. (2017), included an outcome, strategies/best practices to incorporate, and a water cycle diagram previously provided to avatar students. Participants were provided with the materials from the MursionTM scenario to gain an understanding of the avatar students' prior learning about the water cycle. If necessary, participants could review MursionTM resources that aided the participants' knowledge of the water cycle. Participants were tasked with planning questions and facilitating a discussion on the role of

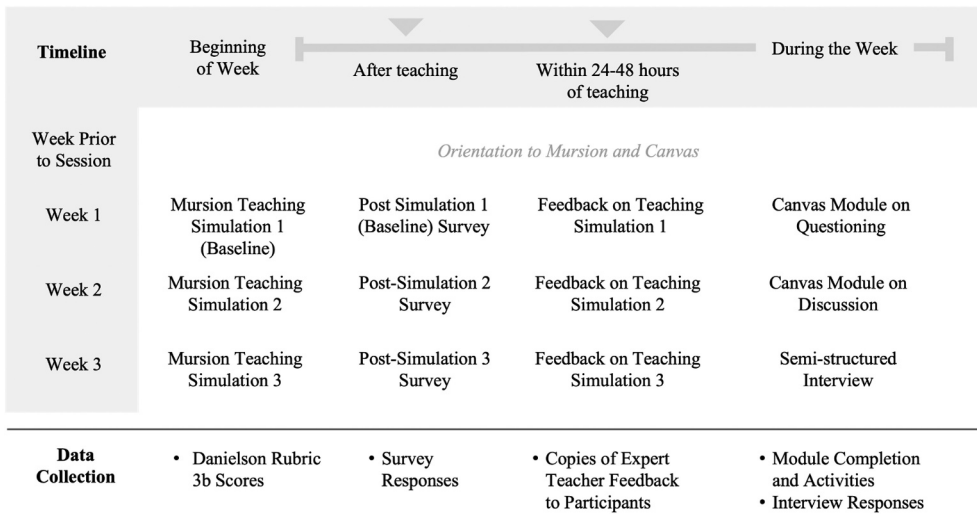


Figure 2. Timeline and data collection for deliberate experiential practice. Timeline indicates the integration of the MursionTM teaching simulation, CanvasTM instructional modules, and expert teacher feedback by week. The data collection for each component is depicted at the bottom of the figure.

the water cycle in the environment. The avatar students knew the steps of the water cycle, so the participants were directed to go beyond the basic review of the water cycle. The same scenario was taught three times. After the first simulation, the CanvasTM platform was used to provide instructional content through learning modules on questioning. After the second simulation, instructional content on facilitating discussions was provided in learning modules.

Timely feedback

Timely feedback for each participant was provided by an expert, mentor teacher. The mentor served as the university host for the teach-to-avatar simulation experience and provided written feedback to each participant within 24 to 48 hours after the completion of the teaching experience. The feedback was guided by the Danielson (2013) rubric for questioning and facilitating discussion provided in Table 1.

Additional feedback was provided by the mentor teacher during the asynchronous learning modules. Participants created possible questions or prompts for facilitating discussion on the role of the water cycle as part of the learning modules. The mentor teacher provided feedback on participants' plans for questioning and discussion prior to the second and third teach-to-avatar simulation sessions.

Participant reflection

The teach-to-avatar simulation sessions were conducted through Zoom video-conferencing technology, thus allowing participants to individually engage in the experience from either the virtual teaching lab on campus or through their personal computer. Each teaching session included the MursionTM host/avatars, the participant, and the university host. The university host was also the mentor teacher who provided feedback on the participant's lesson. The sessions were recorded by the university host using the video recording option.

Table 1. Descriptions of levels from the Danielson (2013) framework for domain 3b.

Rating	Description from Danielson (2013)
Distinguished	"The teacher uses a variety or series of questions or prompts to challenge students cognitively, advance high-level thinking and discourse, and promote metacognition. Students formulate many questions, initiate topics, challenge one another's thinking, and make unsolicited contributions. Students themselves ensure that all voices are heard in the discussion" (Danielson, 2013, p. 63).
Proficient	"While the teacher may use some low-level questions, he poses questions designed to promote student thinking and understanding. The teacher creates a genuine discussion among students, providing adequate time for students to respond and stepping aside when doing so is appropriate. The teacher challenges students to justify their thinking and successfully engages most students in the discussion, employing a range of strategies to ensure that most students are heard" (Danielson, 2013, p. 63).
Basic	"The teacher's questions lead students through a single path of inquiry, with answers seemingly determined in advance. Alternatively, the teacher attempts to ask some questions designed to engage students in thinking, but only a few students are involved. The teacher attempts to engage all students in the discussion, to encourage them to respond to one another, and to explain their thinking, with uneven results" (Danielson, 2013, p. 62).
Unsatisfactory	"The teacher's questions are of low cognitive challenge, with single correct responses, and are asked in rapid succession. Interaction between the teacher and students is predominantly recitation style, with the teacher mediating all questions and answers; the teacher accepts all contributions without asking students to explain their reasoning. Only a few students participate in the discussion" (Danielson, 2013, p. 62).

The Danielson (2013) framework is a holistic approach for providing feedback for improvement of teaching. For this project, Domain 3b, "Using Questioning and Discussion Techniques" (Danielson, 2013, p. 59) was the focus and the only section of the framework used for evaluating teacher candidates. The descriptions of each level for Danielson (2013) Domain 3b. are included in the table.

on Zoom. The video for each participant was then shared with the participant for reflection and saved for later scoring using the Danielson (2013) rubric for questioning and discussion techniques (see Table 1).

Data collection and analysis

Data sources for the case study were multiple and varied as recommended by Stake (1995) and Yin (2017). Data collected for the study included reflective surveys, scores of videos guided by the Danielson (2013) framework on questioning and discussion, and interviews with each participant.

Quantitative data were comprised of ratings from self-report surveys and independently scored videos of simulation teaching sessions. Qualtrics surveys were administered at three points: after the baseline, post-questioning intervention, and post-questioning and discussion intervention. Surveys asked participants to self-report ratings on questioning and discussion skills, evaluate the ease of access to learning and practice through the CanvasTM and MursionTM platforms, and demographic information. Self-report scores were used to determine participants' perceived changes in skills throughout the study.

Questioning and discussion skills were evaluated using the rubric for Domain 3b of the Danielson (2013) framework. Each simulation teaching session was recorded and feedback was provided by a mentor teacher using the Danielson (2013) framework. After the three teaching sessions were completed, two independent scorers experienced with the Danielson (2013) framework and rubric scored the videos of the teacher candidates' simulation teaching sessions. Scores were used to determine changes in participants' questioning and discussion skills throughout the study.

Semi-structured interviews were facilitated by a member of the research team at the conclusion of all components of the intervention. The interviews were approximately 20–30 minutes long and gathered information on participants' perceptions of the intervention, the technology platform, and perceived growth in questioning and discussion skills. Interviews were transcribed and coded by members of the research team who did not facilitate the interviews as described in the following paragraph.

Qualitative interview data was analyzed with deductive coding. Components of Kolb (1984) and Ericsson et al. (1993) were used to predetermine deductive codes outlined in the sample code book presented in Table 2. Deductive coding allowed the theoretical framework to guide data collection and analysis and determine if components of the theoretical framework are connected to the outcomes (Pearse, 2019). Coding and analysis followed what Pearse (2019) termed “theoretically-driven coding” (p. 144) to determine patterns in the data and cross-reference them with patterns or themes in the theoretical framework. Interviews were transcribed and data were coded by the research team using the pre-determined codes. Coded data were compared to themes present in the framework of experiential deliberate practice in relation to participants' perceptions of their skill development (Pearse, 2019).

Table 2. Sample code book for deductive codes with sample coded data.

Code	Code Name	Definition of Code	Sample Coded Data
EDP	Experience—Distributed, Repeated Practice	Experiences that use distributed, repeated practice to improve skills over time	“Doing it [teaching the lesson] over and over again helped me grow.”
ECZ	Experience—Push Out of Comfort Zone	Experiences that push participant out of his/her comfort zone to develop skills	“I think it was really beneficial in most ways. It kind of put you out of your comfort zone at first and the simulation didn't really feel like a simulation.”
ELS	Experience—Low Stakes Environment	Experiences that are low stakes and enable participant to develop skills	“It is less intimidating to start with avatars instead of real students ... could feel a little bit less scared.”
RPTV	Reflection—Personal Teaching Video	Reflection by the participant on his/her personal teaching video to develop skills	“It was helpful. I didn't really want to watch it ... but once I watched it I said, ‘Oh, I could change the wording and do better.’”
RCM	Reflection—Canvas Module	Reflection on peer feedback and learning in the Canvas™ modules to develop skills	“Canvas™ really did help with that [asking questions]. It expanded my view of what I could ask, seeing other people's examples.”
RMF	Reflection—Mentor Feedback	Reflection on mentor feedback prior to Teach-to-Avatar experience in Mursion™ to develop skills	“Without the feedback, I would've not known what I did or why the children were acting that way ... ”
KCMM	Knowledge Construction—Mental Model	Knowledge construction through the creation and/or expansion of the participants' mental model of skills	“The Canvas™ modules that went along with it definitely helped me figure out how to phrase, like, rephrase questions that I was already asking to make them more effective.”
KCG	Knowledge Construction—Goals	Knowledge construction building on goal setting for later application	“I think, you know, the challenge of the whole thing is to come up with good questions.”
ASP	Application—Skill Practice	Application of learned or developed skills in isolated skill practice (including practice in mixed-reality simulation)	“Breaking it down into the two separate pieces really did help me understand how to control it more ... ”

Deductive codes were developed based on the experiential deliberate practice framework from Kolb's (1984) experiential learning cycle and Ericsson et al.'s (1993) deliberate practice. Definitions and sample codes are provided.

Results

Results are organized into the categories of changes in rubric scores for questioning and discussion skill performance, participants’ self-perceptions of questioning and discussion abilities, and impact of the experience. An overview of results is followed by reporting of results as aligned to themes derived from the theoretical framework.

Rubric scores for questioning and discussion skills

Scores from participants’ lessons were used to measure development of questioning and discussion skills. While the Danielson (2013) framework provided a measure for teaching across multiple areas of teaching, this study focused solely on questioning and discussion skills outlined in Domain 3b (Danielson, 2013). If components of questioning and discussion were not observed, participants were given a score of unsatisfactory, even if elements shown may have fit in other domains on the Danielson (2013) framework. As shown in Table 3, all six participants improved by at least one level on the questioning and facilitating discussion portion of the Danielson (2013) framework as determined by the video scorers.

Self-perceptions of questioning and discussion skills

Participants completed a self-report survey at the conclusion of each teach-to-avatar simulation experience related to their perceived abilities over time in questioning and facilitating discussion skills. There were six participants who completed the teaching experiences, but one participant did not complete the final survey. Five of the six participants who completed all three surveys are reported in this section.

In each survey, participants were asked to rate themselves on a five-point Likert scale: not effective at all, slightly effective, moderately effective, very effective, or extremely effective. As shown in Table 4, participants were asked about questioning skills in four parts related to asking thought-provoking and open-ended questions, asking students to justify their reasoning, and asking follow-up questions. Participant responses from the one baseline and two intervention surveys were compared. Table 4 summarizes the areas where participants reported growth in their questioning techniques. Four of five participants self-reported growth in multiple areas of questioning skills, as shown in Table 4, with the remaining participant increasing in one area of questioning skills. However, it should be

Table 3. Participants’ rubric scores from each teaching session.

Rubric Ratings from Danielson (2013) Domain 3b			
Participant	Baseline Teaching Simulation Experience	Teaching Simulation Experience 2	Teaching Simulation Experience 3
Trudi	Unsatisfactory	Basic	Basic
Sandra	Unsatisfactory	Basic	Basic
Edward	Basic	Proficient	Proficient
Robert	Basic	Basic	Proficient
Douglas	Basic	Proficient	Proficient
Anne	Unsatisfactory	Proficient	Proficient

Teaching Simulation Experience 2 is teaching session after the first learning module on questioning. Teaching Simulation Experience 3 is the teaching session after the second learning module on facilitating discussion. The Danielson (2013) rubric on Domain 3b is a four-point scale with the following levels: Unsatisfactory, Basic, Proficient, and Distinguished.

Table 4. Participants' growth in self-reported questioning skills through survey responses.

Participant	Participant Self-Reported Levels		
	Post Teaching Simulation Experience 1	Post Teaching Simulation Experience 2	Post Teaching Simulation Experience 3
Questioning Skill 1: Ability to ask thought-provoking questions			
Trudi*	0	1	0
Sandra*	2	3	3
Edward*	2	2	3
Robert*	1	1	3
Douglas*	2	2	3
Questioning Skill 2: Ability to invite students to justify their reasoning			
Trudi*	0	0	1
Sandra*	2	3	2
Edward*	1	1	3
Robert*	2	2	2
Douglas*	2	3	2
Questioning Skill 3: Ability to ask open-ended questions			
Trudi*	1	1	0
Sandra*	2	2	2
Edward*	1	2	2
Robert*	2	2	3
Douglas*	2	2	3
Questioning Skill 4: Ability to ask follow-up questions			
Trudi*	1	1	0
Sandra*	3	2	2
Edward*	2	2	3
Robert*	2	1	3
Douglas*	2	1	3

Scores indicate self-reported levels in questioning skills after the first teaching simulation experience, the second teaching simulation experience, and the third teaching simulation experience. Positive growth in questioning skills over time are indicated by an asterisk (*). Participants rated themselves on the following Likert scale: Not effective at all (0), Slightly effective (1), Moderately effective (2), Very effective (3), and Extremely effective (4).

noted that two out of five participants' self-report scores on two of the four skills did not increase.

Participants also self-reported growth in their skills associated with facilitating discussion. As shown in Table 5, participants were asked about facilitating discussion skills in four parts that included ability to lead a class discussion, inviting students to comment on each other's responses, engaging all students in the discussion, and encouraging discussion among students. Participant responses from the baseline and post-intervention surveys were compared on the same five-point Likert scale. Table 5 summarizes the areas where participants reported growth in their ability to facilitate discussions. All five participants who completed the post-intervention survey reported growth in at least one area of facilitating discussion skills. Similar to self-reported questioning skills, all participants self-reported an increase in multiple areas of discussion skills as shown in Table 5. However, it should be noted that three out of five participants' self-report scores on three of the four skills did not increase.

One factor that could have resulted in these ratings was a lack of in-depth understanding of questioning and discussion skills. Initial self-report scores may have been slightly inflated due to prior conceptions of questioning, but as participants learned more about the purpose and types of questions the self-report scores may have been more accurate. Participants originally viewed the purpose of questioning as a means of getting correct answers and not as a tool for engaging students in deeper thinking. This was

Table 5. Participants' growth in self-reported discussion skills through survey responses.

Participant	Participant Self-Reported levels		
	Post Teaching Simulation Experience 1	Post Teaching Simulation Experience 2	Post Teaching Simulation Experience 3
Discussion Skill 1: Ability to lead a class discussion			
Trudi*	1	0	0
Sandra*	2	3	3
Edward*	2	2	2
Robert*	2	1	3
Douglas*	2	2	3
Discussion Skill 2: Ability to invite students to comment on each other's responses			
Trudi*	0	0	0
Sandra*	1	2	3
Edward*	2	1	3
Robert*	1	1	3
Douglas*	0	1	4
Discussion Skill 3: Ability to engage all students into the discussion			
Trudi*	0	1	1
Sandra*	2	2	2
Edward*	3	3	3
Robert*	3	2	4
Douglas*	1	2	4
Discussion Skill 4: Ability to encourage discussion among students			
Trudi*	0	2	1
Sandra*	1	2	3
Edward*	1	3	3
Robert*	2	2	1
Douglas*	1	2	3

Scores indicate self-reported levels in discussion skills on the first teaching simulation experience, the second teaching simulation experience, and the third teaching simulation experience. Positive growth in discussion skills over time are indicated by an asterisk (*). Participants rated themselves on the following Likert scale: Not effective at all (0), Slightly effective (1), Moderately effective (2), Very effective (3), and Extremely effective (4).

supported when Robert said that he was not “used to writing those [higher level] types of questions.” Robert explained how his perception of questioning as a teaching tool changed throughout the project, evolving from eliciting answers to spurring thinking and explanation.

Similarly, the asynchronous module offered between Post-simulation Teaching Experience 2 and Post-simulation Teaching Experience 3 focused on skills for facilitating discussions. The introduction of additional information related to questioning and discussion may have impacted participants' self-perception in the holistic view of skills inclusive of both questioning and discussion skills. As participants reflected on their ability to engage students in questioning and discussion, the self-perception ratings may have been impacted by new knowledge about facilitating discussion and implementation of these skills in the simulation teaching experience.

Impact of experience on questioning and discussion skills

Data collected from semi-structured interviews with individual participants were coded using deductive analysis to identify themes consistent with the theoretical framework of experiential deliberate practice. These themes included experiences, reflection, knowledge construction, and application. The data were organized by these themes.

Experiences

Concrete experience was identified by participants as important in supporting growth in questioning and discussion facilitation skills. The setting of experience in the Teach-to-Avatar program allowed participants to engage in a low-stakes experience. Additional sub-themes included moving out of their comfort zones and distributed, repeated practice.

Lower stakes environment

The concrete experience Teach-to-Avatars provided participants the opportunity to practice in a low-stakes atmosphere. Multiple participants discussed teaching to avatars as reducing anxiety because they knew they were not “hurting” students if they made mistakes when implementing skills and strategies in the Teach-to-Avatar classroom. The opportunity for repeated practice with the same students in the same setting was also identified as reducing anxiety and increasing participant comfort in the experience.

Beyond comfort zone

The level of comfort varied as participants repeated the teach-to-avatar simulation experience. Anne noted that he became more comfortable as time went on, but there were always parts that went beyond his comfort zone. Anne stated that “repetition made you comfortable with a portion of it, so you can focus on the things you do need to work on.” The teach-to-avatar simulation became more comfortable as participants learned the technology and the avatar students, but there were components of practice that remained beyond the comfort zone.

Even though participants’ comfort improved as they practiced implementing their new learning on questioning and discussion facilitation skills, the Teach-to-Avatar experience did push participants beyond their comfort zones. Edward noted that, “I think it was really beneficial in most ways. It kind of put you out of your comfort zone at first and the simulation didn’t really feel like a simulation.”

Edward shared the consensus idea that, “It [simulation teaching experience] didn’t really feel computerized most of the time.” Participants reported preparing for experiences that were true to “real life” teaching experiences pushing participants beyond their comfort zones by interacting with the avatar students. The avatar students were perceived by participants as viable stand-ins for traditional classroom teaching experiences, which included participants challenging themselves to plan for “real” teaching experiences.

Distributed, repeated practice

The use of MursionTM to facilitate the Teach-to-Avatar simulation experiences allowed participants to teach the same lesson three times to the same group of avatar students. As noted in the previous section, the teach-to-avatar experiences became more comfortable and provided the opportunity for distributed, repeated practice. Participants recognized that the simulation teaching experience provided a consistent environment to practice. Additionally, participants valued that each experience with the avatars was a fresh start without the prior knowledge or influences that would be present in real students. Participants’ self-perceived mistakes or areas of improvement identified in feedback did not persist from one teaching session to the next and therefore allowed repeated practice distributed over time.

Participants reported that the ability to go reflect, consider feedback, and repeat the teaching scenario was valuable in their improvement. As Robert stated:

I think it is really important to practice over and over again. The more times I do something the better I am, so I tend to read things over and over again and do things, physical, actual things over and over until repetition makes it second nature. So, I think it is really good to do that.

Participants connected distributed, repeated practice provided opportunities to change and develop skills highlighted in feedback from the expert teacher and asynchronous learning modules.

Reflection

Participants were asked to review the videos of their teaching experiences and reflect on feedback from an expert teacher. These two components prompted participants to connect practice and feedback through guided self-reflection, as described by Douglas:

Without the feedback, I would've not known what I did or why the children were acting that way. I mean, I think even if you just went back and watched your video without that feedback, you might watch that video and be like, "Well, I don't know why Carlos doesn't want to answer this. Why does he feel uncomfortable? I don't understand." You know, because maybe it's something that would not have made me feel uncomfortable as a child. But when you can read that feedback and then put it with that, you go, "Oh. OK, I see."

Review of recorded lessons to prompt reflection and feedback were identified by participants as influential factors to inform their development.

Knowledge construction

As part of the asynchronous learning modules, participants developed questions and planned for use of strategies to facilitate discussion prior to the two post-intervention teaching experiences. Participants set goals for themselves as part of this planning. Setting goals and new learning that expands mental models are two components of abstract conceptualization. As described in the following sections, participants found both setting desired goals and new learning that expands the mental model to be valuable in increasing their capacity and confidence for engaging students in questioning and discussion.

Set desired goals

In the first learning module, participants set a goal for questioning and then set a goal for facilitating discussion in the second learning module. These goals were noteworthy for participants in helping them focus on and implement certain techniques. Setting goals improved participants' awareness of strategies used and potential for improving them in future lessons.

In addition to raising awareness, setting goals stemming from the learning modules helped participants feel more confident prior to teaching. As described by Sandra, confidence and goals can help guide implementation and teaching practice. She stated that she "became more confident" as she worked toward her goals throughout each round. The project's broad goal of improving skills for questioning and facilitating discussions led to participants focusing their attention on their actions, using examples provided in learning modules, and using feedback from peers and the mentor teacher to rethink and revise questions and discussion prompts. Setting goals, such as asking more open-ended, higher-order questions and increasing

engagement in discussions by asking students to talk to each other and build on their responses, helped participants prepare and follow through with a focus on isolated skills contained in feedback and learning modules.

Expand mental model

Learning modules were asynchronous but provided opportunities for learning and interactions with peers through discussion posts and participant-created videos. New knowledge presented through learning modules was focused on questioning and discussion facilitation skills. As presented previously, participants valued the breakdown and focus of the modules. However, beyond the isolation of skills, participants shared a belief that the new learning expanded their thinking and therefore their mental model of the purpose and use of questioning and discussion facilitation skills.

In reference to influences on development of skills, Trudi shared that “the CanvasTM modules that went along with it definitely helped me figure out how to phrase, like, rephrase questions that I was already asking to make them more effective.” Participants recognized that the questions could be asked for different purposes. The questions asked by participants improved from baseline lessons and included varied approaches thus improving the types of questions and providing opportunities for deeper student learning. Participants found value in the feedback from peers during the learning module. This was summarized by Douglas’s response that “seeing other people’s questions that they’d come up with kind of like expanded my own view of what I could ask.”

While learning modules provided a first step, Robert emphasized the need for ongoing practice to further develop. He expressed that “developing these types of questions will come with practice.” He explained that continued practice and application in the classroom will be beneficial for both the teacher and students.

Application

Participants noted that teaching requires many different skills. One advantage of the Teach-to-Avatar simulation experience was the focus on implementing the skills of questioning and facilitating discussion. This isolated skill practice of the studied experience focused participant attention on questioning and facilitation of discussion and not on classroom management or content. Participants were able to plan for asking questions and facilitating discussion within a given topic, the water cycle, without an emphasis on managing other student behaviors.

Participants found the breakdown of questioning and discussion in the learning modules impactful during teaching simulation experiences. Edward summarized the impacts by stating:

Breaking it down into the two separate pieces really did help me understand how to control it more. So, learning how to ask the thought-provoking questions and then actually practicing asking those questions before I try to lead a discussion is very helpful because it let me realize what I needed to do or at least the questions that would have them thinking about it. Like, I want to ask them thought-provoking questions about the topic, and I don’t want to get them distracted. I want them thinking of their answers and then going back the second time and trying to continue on with that discussion, oh, it was so much helpful!

In addition to the isolated skill practice in the teaching simulation experience, asynchronous instruction learning modules further focused the practice on either developing questioning skills or strategies for facilitating discussion. Participants found the separation of questioning and discussion skills useful in aiding their focus and isolating skills to be practiced with peers in the learning module activities as well as when teaching to the avatars.

Participants found that the examples of each skill provided in the learning modules allowed them to hone parts of skills and apply their learning to their practice. Sandra summarized the opportunity of growth provided in her explanation that she would “go off of what your [project provided] examples were in the [learning module] and build on mine to make them better.”

Furthermore, Trudi explained that focusing on and improving one skill would positively influence the other skill. In regard to separating skills, she stated:

That way you feel more confident in one particular task that you need to make sure you're good at. Like the questioning, asking and questioning, you want to make sure you are asking good questions. But then once you know you're asking good questions, it's easier to guide it, guide the discussions, and keep everyone on track and everything.

Sandra shared a similar sentiment in her thoughts that separating the skills “helped you focus on one task at a time and then helped better each other [skills].” These participants described the theme of how the initial separation of questioning skills from facilitating discussion allowed an improvement in questioning that subsequently aided the development and implementation of skills for facilitating and guiding discussions.

Discussion

Questioning and discussion facilitation skills were positively impacted for the six participants in this study. The influence of feedback, asynchronous instruction, and deliberate experiential practice provided a means for informing and influencing participant skill acquisition and implementation. The improvement of questioning and discussion facilitation skills from teaching experiences paralleled the participants' self-perceptions of skills.

Teaching practice ratings and participant perceptions

The Danielson (2013) ratings of participant teaching increased by at least one level for all participants. The five participants who completed the surveys also all reported an increase in their perceptions of questioning and discussion facilitation skills. In the interviews at the conclusion of the experience, participants identified components of experiential (Kolb, 1984) and deliberate (Ericsson et al., 1993) practice as positive factors in developing skills. This is consistent with research of Klassen et al. (2021) that structured virtual activities can contribute to skill development.

Connections between instruction and practice

Consistent with the findings of Peercy and Troyan (2017), this study shows that instructional activities linked with practice opportunities are important in developing teacher

candidate skills. Feedback and asynchronous instruction that incorporate abstract conceptualization and active experimentation were coupled with Teach-to-Avatar simulation experiences that provided a link between instruction and practice. This study demonstrates how experiential deliberate practice using online simulations and instruction can provide necessary practice opportunities for teacher candidates. Participants engaged in reflective observation consistent with Kolb (1984) through guided self-reflection (Ericsson et al., 1993) resulting in improved questioning and discussion skills.

Furthermore, this study builds on the conclusion of Klassen et al. (2021) that virtual experiences designed with an intentional focus could aid in teacher candidate skill development. As reported by participants, asynchronous learning modules were effective in conveying learning focused on supporting skill development. The learning modules helped to breakdown skills, engage participants, and aid in improving the targeted skills. As evidenced by participants' interview responses, concrete experience with distributed practice that pushed participants out of their comfort zones (Ericsson et al., 1993; Kolb, 1984) was one component to promote improved questioning and facilitating discussion skills as measured by the Danielson (2013) framework.

The skills learned in the instructional modules needed to be transferred and implemented in teaching experiences. The teaching simulation experiences offered participants the opportunity to engage in applying new learning and to reflect on their practice. The instructional modules were foundational to applying skills in the teaching simulation experiences. Similar to impacts discussed in Helms-Lorenz et al. (2016) and Karbownik (2014), the combination of asynchronous instruction with teaching simulation experience in this study supported the development of skills important for teacher success in the classroom.

This study focused on the implementation of a mixed-reality virtual online simulation with both synchronous and asynchronous components to aid in the development of questioning and discussion skills. The results demonstrate increases in science teacher candidates' performance ratings and self-perception of questioning and discussion skills. While the impact on long-term effects is an area for future study, the demonstrated growth in this study shows the potential of applying deliberate experiential practice using the teaching simulation experience on MursionTM coupled with skill development in learning modules. Even with limited teaching simulation time, the accentuated skill development over three weeks is a strength in preparing science teacher candidates.

Consistent with the work of Sayeski et al. (2017), skill development resulted from a combination of synchronous and asynchronous experiences. The combined online holistic approach used in this study is aligned with experiential deliberate practice theory in the teach-to-avatar project (Ericsson et al., 1993; Kolb, 1984; Sayeski et al., 2017). Although this research study had a small sample size of six participants and was a convenience sample, the research provides insight into the design of online and virtual learning components for developing questioning and discussion facilitation skills (Yin, 2017).

Broader implementation of the Teach-to-Avatar project can aid in further addressing the gap in research on the use of asynchronous learning and virtual teaching platforms to support the development of teacher candidate skills. The impact of the Teach-to-Avatar project in different institutional settings, can further add to the knowledge base and aid in redesigning experiences that provide opportunities for practicing skills that mitigate science teacher attrition (Helms-Lorenz et al., 2016; Karbownik, 2014).

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