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Designing Digital Clinical Simulations to Support Equitable Mathematics Teaching

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Abstract

This paper presents design principles to create digital clinical simulations that support pre-service mathematics teachers in developing equitable teaching practices: first, how to contextualize moments of decision-making; second, how to illustrate the complexity of decision-making through sequential pathways; and third, how to emphasize the broader consequences of decisions about equity. By focusing on the intersection of instructional decision-making and power dynamics in classrooms, the paper addresses how to design simulated approximation experiences that elicit reflection about deficit perspectives and systemic inequities in mathematics education. The authors illustrate how such design principles, when coupled with improvisational teaching decisions in a simulation made on the Teacher Moments platform, enable reflection on how a teacher's instructional choices can influence student participation, cognitive demand, and the redistribution of power. This work contributes to the field of mathematics teacher education by providing a framework for integrating critical equity considerations into the design of practice-based learning environments.

Introduction

Pre-service teachers, when learning to teach, are often introduced to the general concept of instructional decisions (i.e., the verbal and nonverbal actions a teacher can intentionally choose to make) to enable new teachers to develop routines that support learning (e.g., questions to check for understanding or provide feedback, asking students to talk to a partner before sharing their thinking out loud). It is common to teach new mathematics teachers particular instructional decisions framed as "better" mathematical instructional decisions because they have the potential to elicit high quality mathematics thinking from students (Ball & Forzani, 2011; McDonald et al., 2013; Philip et al., 2019). When these instructional decisions are positioned as "best practices," it suggests they will achieve high-quality mathematics thinking no matter the teacher, no matter the students, and no matter the context of the classroom. Then, when these instructional decisions do not achieve the expected results, pre-service teachers can place blame on students (Martin, 2009; Philip et al., 2019). Therefore, a tension can arise when these instructional decisions do not work as expected within real classrooms and with real students, which may fuel deficit perspectives about students that prevent the development of equitable mathematics learning environments.

To avoid these potential consequences, we ask how can designers support pre-service teachers to reflect on and address these tensions when they emerge? Teacher decisions operate within contexts where the distribution or shifting of power can inform content-based decisions and interpersonal interactions, and vice versa (Chen et al., 2021; Chen & Horn, 2022; Yeh & Rubel, 2020). Larger constructs of power such as white supremacy or systemically racist educational legislation intentionally or unintentionally fuel teachers' decisions that "reproduce, challenge, and/or transform systems of hierarchies … in classrooms" (Philip et al., 2019, p. 9). If mathematics teacher educators struggle to articulate the ways in which power can influence *instructional decision-making*, pre-service mathematics teachers may make instructional decisions in a way that potentially harm the students who are already the most hurt within mathematics classrooms (Battey & Leyva, 2016; Hand, 2012; Martin, 2012). For example, a teacher may lower the cognitive demand of tasks for their students, despite an intention of making them more accessible, based upon an underlying deficit perspective about the ability of their students of color to do more complex work (Benoit et al., 2025).

We wish to support the development of *equitable mathematics teaching*, by which we mean instruction that involves in-the-moment choices that explicitly attend to the distribution or manifestation of power. For this goal, pre-service teachers need opportunities to be able to recognize the manifestation of power in their classroom and to understand how it is impacted (or not) by certain instructional decisions. That is, a pre-service teacher needs to attend to both the ways in which power is operational in the moment, and the ways in which it develops across multiple parts of a lesson (Chen et al., 2021; Chen & Horn, 2022; Martin, 2009). For instance, imagine a pre-service teacher who has learned that balancing student voice within a classroom may be supported by an instructional decision such as a "turn-and-talk" (Chapin & Anderson, 2013) to allow many students to participate. Although the pre-service teacher may be making an instructional decision with an intention of teaching mathematics equitably, this instructional decision does not necessarily function as such if the way in which students are offered opportunities to join the classroom community does not redistribute power in that community. For example, one partner may share their idea while the other stays silent because the teacher earlier acknowledged the pair as correct based on the one student's response. In these cases, the instructional decision, although having the potential to *shift* who holds power, may instead *perpetuate* the status quo of who holds power in the classroom. Or, a teacher may ask a student for their thinking, but then not acknowledge their thinking by saying they are wrong, or respond to their thinking without attending to any of the students' actual ideas (e.g., immediately sharing a specific procedural strategy). Thus, equitable mathematics teaching requires that teachers understand the subtle ways instruction can reinforce inequitable structures and to recognize potential opportunities to disrupt inequity.

This paper shares our work in designing opportunities for pre-service mathematics teachers to interrogate the relationship between power and instructional decisions. We do this by designing *digital clinical simulations*. These are online experiences for pre-service teachers to role play in professional scenarios, such as talking to students in a mathematics lesson or a parent in a conference. Using a platform called *Teacher Moments,* we have designed and implemented digital clinical simulations that elicit and record pre-service teachers' role-playing decisions. We use these simulations to provide pre-service teachers opportunities to reflect and become aware of how their choice of instructional decision influences who may hold power in a classroom. We have come to recognize certain design

considerations that help forefront equity when making instructional decisions in digital clinical simulations. We share these insights to support designers, teacher coaches, researchers, students, or any decision-maker to similarly create practice spaces for pre-service teachers that authentically surface moments regarding power within mathematics classrooms.

Theoretical Perspectives

Our design work rests on the foundation of equitable pedagogies research done within mathematics education. Our first theoretical consideration focuses on nuancing the way in which power is grounded and expressed within the choice of instructional decisions across a variety of scenarios in a mathematics classroom. When an instructional decision is understood for how it (re)distributes power, it can reveal how individualized decisions function within larger systems of oppression (Chen & Horn, 2022). Instructional decisions have the potential to support, or further harm, student learning within small group discussion, which typically follows the launch of a task for students to work collaboratively on a mathematics problem (Smith & Stein, 2018). Although small group discussions are often seen as part of supporting equitable mathematics learning (Berlin & Berry, 2018; Gutiérrez & Calabrese Barton, 2015), they are also a place where equitable practices that look and sound similar to a teacher can potentially shape different experiences for young people. When students are in small groups, the choices a teacher makes can influence which students hold speaking rights or have access to increased cognitive demands of a task (Langer-Osuna, 2017, 2018). Further, a teacher's choices can intentionally or inadvertently (re)center the ideas of students whose cis-white heteronormative male identities are privileged in mathematical activity and spaces (Battey & Leyva, 2016; Hand, 2012; Leyva, 2017; Martin, 2012). The assignment and affirmation of relative status in the classroom (e.g., who is viewed as most competent), which influences the access to cognitive demand and the right to speak and share ideas, can, without intervention, reflect the divisions of race and culture in the mathematics classroom. A teacher who makes instructional decisions which support students in having a higher status, access to increased cognitive demand, or opportunities to speak when they are marginalized in other communities challenges a *culture of exclusion* (Louie, 2017).

Our second theoretical consideration focuses on the way in which power is grounded and expressed in terms of the potential ideological perspectives that inspire instructional decisions in classroom scenarios. To connect the choice of instructional decisions to power, a pre-service teacher needs to understand how ideological perspectives about who does mathematics and what mathematical success looks like impacts how they perceive and make improvisational decisions (Louie, 2017; Louie, 2019; Chen et al., 2021). A teacher's ideological perspectives about young people (be it explicit or implicit) can shape pedagogical choices in the classroom, which in turn can shift who has power. Deficit perspectives, or ideological perspectives that perpetuate the idea of students of color, non-male students, or their intersections as somehow lacking competence in the mathematics classroom (Berry, 2008) can lead to instructional decision-making that reinforces assumptions about what mathematics is valuable and who is able to do mathematics (Louie, 2019). When a teacher has low expectations for students, they often make curricular decisions that remove any opportunity to engage in mathematical content knowledge beyond rote memorization. These resulting instructional choices are most often

experienced by student populations of color due to a culture of whiteness that connects low expectations and race, particularly within mathematics classrooms (Battey & Leyva, 2016; Louie, 2019). Therefore, it is critical for teachers to recognize and challenge deficit perspectives about students who are historically marginalized in order to create equitable learning experiences for young people (Berlin & Berry, 2018; Martin, 2012).

Situating Our Work: Why We Design Using Digital Clinical Simulations

In our design of digital clinical simulations, we build from literature where mathematical teacher educators design opportunities for pre-service teachers to rehearse the skills of teaching, such as making instructional decisions. Approximations of practice (Grossman, Compton et al., 2009) allow pre-service teachers to engage with opportunities that mimic classroom experiences (Ball & Forzani, 2011). Before teaching in schools with students, approximations can be used to provide pre-service teachers an opportunity to train specific skills (Herbst et al., 2011; Thompson et al., 2019). Approximations are often paired with feedback and reflection opportunities (Dotger, 2015; Self & Stengel, 2020). Since approximations provide opportunities for pre-service teachers to relate their classroom practice to theory, the design and use of approximations support bridging theory and practice (Ball & Forzani, 2011; Grossman, Compton et al., 2009; Grossman, Hammerness et al., 2009).

Simulations, broadly, involve role playing by a pre-service teacher where they respond to an external prompt or person who is designed to react in particular ways based on the pre-service teachers' responses (Thompson et al., 2019). The design of simulation scenarios with live actors intentionally situates the work done by teachers in relation to actor personas with rich histories and contexts (Dotger & Chandler-Olcott, 2022). For instance, Shaughnessy and colleagues (2019) designed simulations for pre-service teachers to try specific instructional decisions (such as sentence stems to facilitate mathematical discussions) with live actors role playing as students. Live actors were given personas that included particular ways of interpreting the mathematics, particular ways of solving the problem, and particular ways of emotionally and behaviorally interacting with pre-service teachers. In these types of simulations, when pre-service teachers ask the live actors questions, the actors respond as students using particular phrases depending on the pre-service teacher's prompt.

Building from the work with live actors, digital simulations are microworlds or environments built within technological platforms that allow a participant to engage within a fictional scenario. These online platforms sometimes use one or more live actors to voice student avatars by following a script of responses (Cohen et al., 2020). Because these digital simulations include opportunities for teachers to engage in the practice of teaching in a fictional scenario, some online platforms have been developed and used within pre-service mathematics teacher education as a form of approximation. For example, some platforms allow participants to speak and write responses to visual prompts in a scenario (e.g., Thompson et al., 2019; Reich et al., 2018). Others use interactive storyboarding (e.g., cartoon scenes of a classroom where characters have speech bubbles) to allow pre-service teachers to script decisions of a fictional teacher in a cartoon scenario (e.g., Herbst et al., 2014; Herbst et al., 2011). This body of work has demonstrated that scripting can be used for pre-service teachers to practice both teaching non-mathematics specific (e.g., a turn-and-talk) and mathematics specific instructional decisions (e.g., probing questions for students to share their mathematical thinking).

However, both live and digital approximations of practice have the potential to reduce classrooms to an oversimplified environment, artificially separated from the socio-historical and socio-cultural complexities of real-life mathematics classrooms. Approximations can sometimes position the choice and debrief of instructional decisions as "right" or "wrong," which can separate or ignore the role of historical and systemic hierarchies in the selection, use, and effect of instructional decisions (Philip et al., 2019, p. 8). The teacher's reflection on their instructional decisions, particularly with a consideration of the ways that power is distributed in relation to systemic hierarchies, can help highlight how their individual decisions function within larger systems of oppression (Chen & Horn, 2022). If power is not explicitly considered as part of reflecting on approximations, pre-service teachers can position students at fault when an instructional decision recommended to them "fails" (Battey & Levya, 2016; Mendoza et al., 2021; Philip et al., 2019, Shah, 2017). Therefore, not connecting power within classroom spaces and teacher decision-making within approximations of practice can perpetuate deficit perspectives about students.

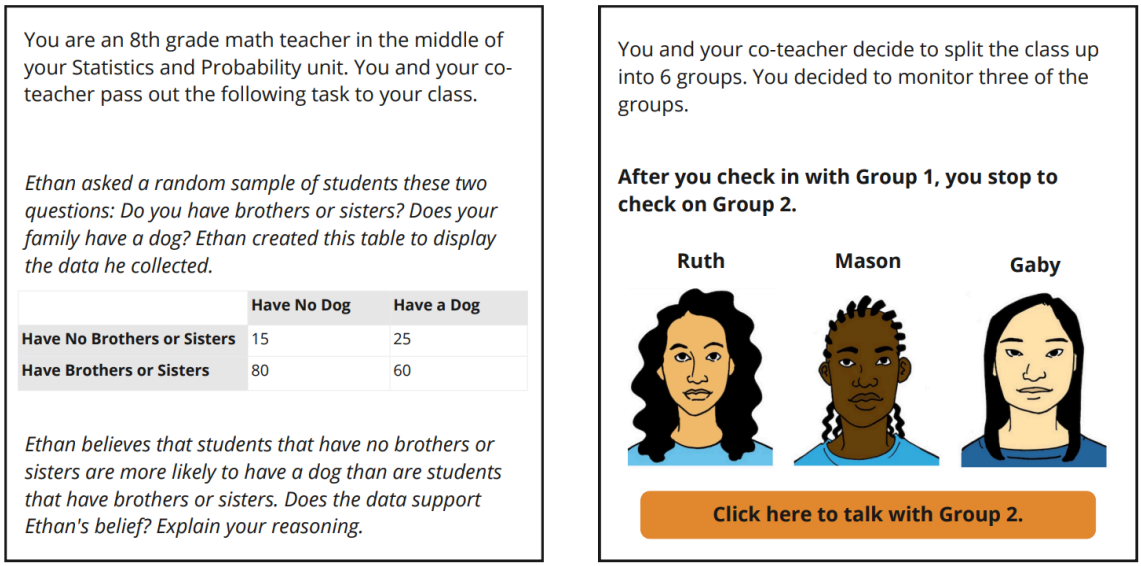
Some researchers have started to develop digital simulations that focus on moments of improvised decision-making (e.g., immediately, without preparation) (Reich et al., 2018; Reich, 2022). These types of digital simulations, sometimes referred to as *digital clinical simulations,* focus on very short segments of activity, such as a 2-minute classroom interaction. These short digital clinical simulations provide many opportunities to rehearse making decisions while considering the ways in which these decisions may contribute to systemic hierarchies (Buttimer et al., 2022). Pre-service teachers can verbally try out different instructional decisions across multiple moments in a scenario, which change depending on their choices within the simulation.

Simulation Platform: Teacher Moments

Although simulations do exist that focus on incidents about the shifting of power between students in mathematics classrooms (Self & Stengel, 2020), there is opportunity for digital clinical simulations to be made that are mathematics specific, focus in on the shifting of power, and do not rely on the use of live actors (Herbst et al., 2014; Herbst et al., 2011). This paper explores how digital clinical simulations are made within the Teacher Moments platform so that pre-service mathematics teachers can practice experiencing and recognizing moments of teaching that involve power dynamics.

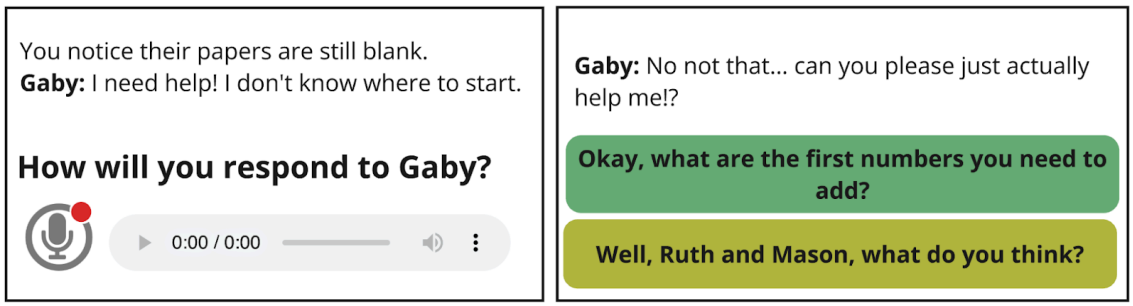
Within a Teacher Moments simulation, a pre-service teacher is introduced to a detailed classroom scenario and asked to respond at different moments to different types of visual prompts in-the-moment (Sullivan et al., 2020) (Figure 1). This choose-your-own-adventure structure of Teacher Moments means improvisational responses lead novice teachers to different prompts.

Figure 1 – Contextual Information Provided at Beginning of Digital Clinical Simulation



There are several ways in which teachers are given opportunities to respond within a simulation. When asked to respond, pre-service teachers are prompted to either select from two to three pre-written text responses or to record an auditory response (Figure 2). Recording responses involve the *record points*, as indicated by the microphone symbol. Potential responses also involve the green *selection buttons*, as indicated by green boxes with text inside of them. The green selection point buttons will then lead to different outcomes and therefore a different subsequent visual prompt. So, specific moments in the simulation may lead to one of up to three different prompts following an improvisational decision. Together, we will refer to *decision moments* as the points where a pre-service teacher makes a verbal response at a *record point*, or makes a choice of one of the *selection buttons*. The set of instructional decisions a teacher makes across these decision moments allows improvisational decisions within a sequence of decisions, allowing novice teachers to reflect on shifting power dynamics over time in relation to their choices.

Figure 2 – Response Types Available within Digital Clinical Simulation



Before sharing the design principles, we want to acknowledge some tensions between the opportunities afforded by digital clinical simulations and our intended theoretical framework. First, we recognize these digital clinical simulations require a debrief conversation, a later step that is not presented in this article. We unpack the process and potential of later reflections in other work (see Barno, 2025a; 2025b). Second, there must also be a discussion of what is not part of the simulation design, such as the simulated students' tone, emotional state, prior knowledge, or presumed relationship with their "teacher." Any dialogue in a simulation can contain a particular tone or be laden with specific emotions that could influence a teacher's decision-making.

Designing Simulations within Teacher Moments

In this section, we will describe three design principles that we used in our digital clinical simulations. To support pre-service teachers in confronting ways in which power is present within classroom interactions, we have designed with a focus on decisions that are both common but also surprisingly complex, and often made in different ways depending on purposes or ideological perspectives. We illustrate these design principles by providing an example of one digital clinical simulation we have designed and used in a secondary mathematics methods class. In this simulation, pre-service teachers were prompted to engage with a fictional small student group that was designed to exhibit common group dynamics. Although there are multiple small groups in our scenario, this illustration will focus on "Group Two." This part of the simulation challenges a pre-service teacher to individually make decisions where their awareness of power and equity may (positively or negatively) impact the cognitive demand of a mathematics task for the students in that group.

Design Principle #1: Intentionally Contextualize Moments of Decision-Making

We designed each simulation to start with a concise description of the scenario. Since one purpose of the simulation is to position any particular decision as part of a sequence of many decisions (see Design Principle #2), we present scenario details as an informative context for those decisions to rely upon. Specifically, the scenario included some biographical information about a small number of student characters; information about the content goals of the lesson; and a description of what had occurred in the lesson prior to the start of the simulated scenario. However, the amount of contextualization leaves room for ambiguity for the pre-service teacher's interpretation of the moment, which in turn allows power dynamics that influence real-life moments to potentially arise in the teacher's instructional decision-making.

For example, the way a pre-service teacher would respond to a student request for help in the simulation depends on what they know about the fictional student, whether the task is unfamiliar to the students, and how familiar the student is with the underlying mathematical content of the lesson. Although not provided in the simulation described here, this information can be included in the design of the platform. If these types of details are not provided (as is the case in the simulation described in this paper), then the pre-service teacher could make assumptions about these characteristics (as one might do outside of a simulation). For example, in our scenario, we wrestled with whether we would explicitly state at the outset that the participant should not indicate how to approach the problem in a particular way so that students need to spend time strategizing. By not including this information, pre-service teachers are positioned to make assumptions about what the students in the simulation understand about the task (Self & Stengel, 2020). Pre-service teachers are then faced with a decision that all teachers experience in the classroom —whether, and how, to begin an interaction with a small group working on a task. When a pre-service teacher assumes something before engaging with the group (e.g., that a student is avoiding work), they may decide to say something aligned with that assumption (e.g., asking the student how they think they should get started or implying the student needs to focus). However, if a pre-service teacher makes a different assumption (e.g. that one student understands the task better than their peers in the group), their response may be similar but with different supporting ideological perspectives (e.g. asking a student if they think they should get started by talking to their more knowledgeable peer, or implying the

student needs to focus and can rely on their classmate for support to do this work). These multiple opportunities to make decisions, and unpack the assumptions behind those decisions, provide an opportunity for pre-service teachers to recognize ways in which their worldview can lead to certain assumptions, which in turn lead to certain decisions. This opens an opportunity for pre-service teachers to begin to question their assumptions and move toward making different decisions in the future.

In our example simulation, pre-service teachers are prompted with information about the content of the class they are teaching, the mathematical tasks that students in the simulation are working on, and the groups of students with whom they are interacting. In this simulation, the participant is positioned as an eighth-grade mathematics teacher in the middle of a lesson in their statistics and probability unit. They are also informed that they have just launched a mathematical task for students to work on in small groups, with a particular focus on examining patterns of association within two-way frequency tables. Next, the pre-service teacher is told they are about to check in on three different small groups, without a clear directive of what to specifically check in about. Following this, and after an interaction with another small group, the simulation prompts pre-service teachers to respond to student Group Two (Figure 1).

In the simulation, Group Two includes three fictional students: Ruth, Mason, and Gaby. Although the simulation shows pictures of the students, there are no written details about their identities given to the pre-service teachers. The fictional students in our simulations are not introduced with any explicit labels indicating any ethnic, racial, sexual, or gender identities. Although any individual student holds an intersectional and multifaceted identity, we believe this design sets up an opportunity for pre-service teachers to think about the layers and role of assumptions, and how these may or may not shape their instructional decision-making. For example, if we designed the simulation to include informing the participant that, “Gaby is an Asian female,” this design choice has the potential effect for pre-service teachers to assume Gaby is exceptionally strong at mathematics due to the model minority myth (Chen & Buell, 2017; Jett et al., 2022). Yet, when we do not indicate Gaby’s race or gender explicitly, the pre-service teacher may make assumptions about Gaby’s identity that informs their later reflection and highlights a potential reason behind their assumptions about Gaby’s mathematical ability. Another example includes assumptions about Gaby in relation to what she says. For instance, Gaby’s script could imply that she does not want to work hard or does not understand the content because she continually asks for detailed next steps. This design choice allows pre-service teachers to unpack their assumptions in relation to learned helplessness or understanding that Gaby’s persistence in asking for help may be due to her experiences that suggest this is how she finds success in mathematics classes. So, while this assumption may conflict with an assumption about Gaby’s success due to the model minority myth, it is important for pre-service teachers to recognize both assumptions and how they could implicitly shape their decision-making about how to interact with Gaby.

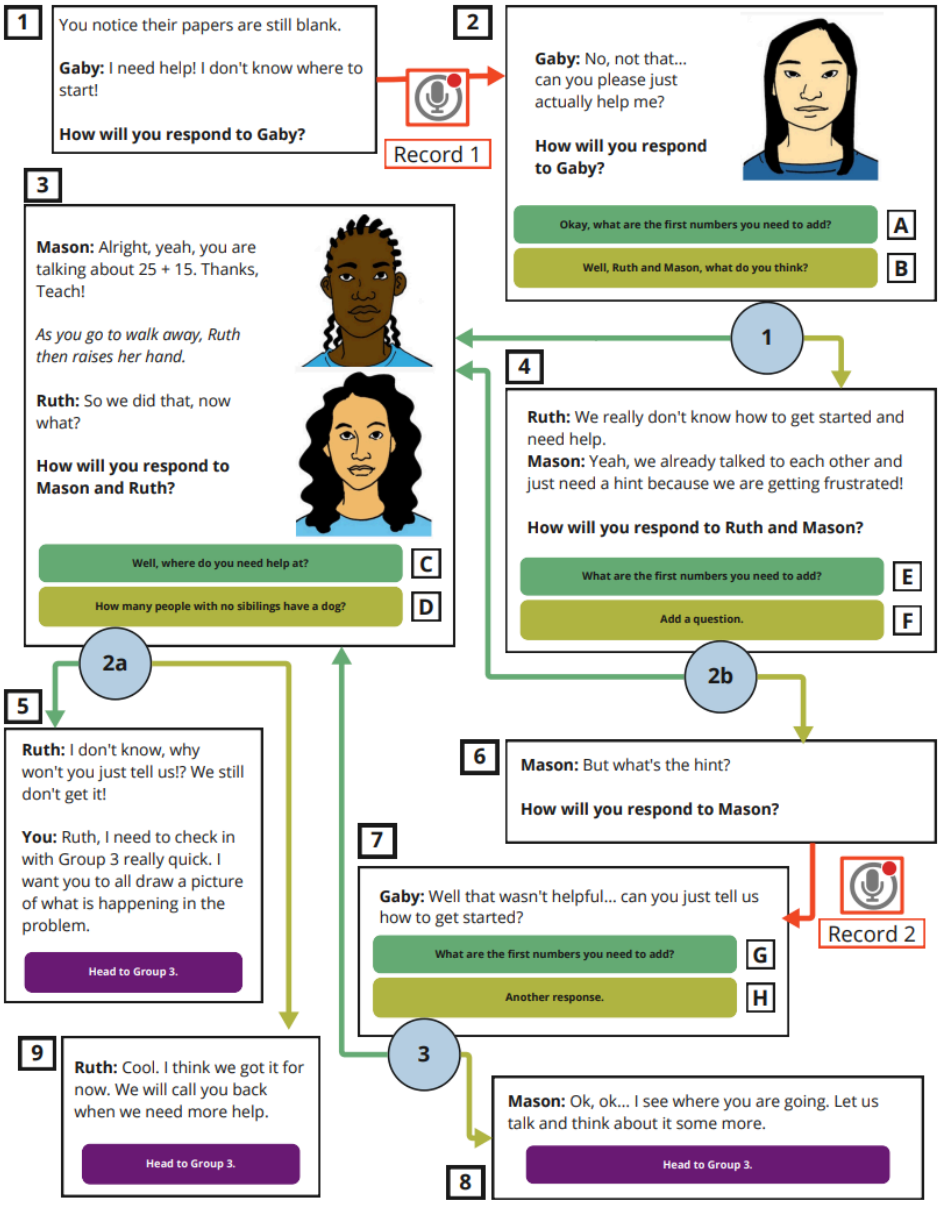
Design Principle #2: Highlight Complexity of Decision-Making through Sequences

Designing a simulation with attention to possible sequencing of decisions allows for pre-service teachers to experience a changing scenario based on the decisions they make. *Teacher Moments* simulations are designed where a decision made at a particular moment is improvisational. Once a prompt in a simulation is given, the pre-service teacher must respond in-the-moment (as opposed to having a pre-planned response) to that given part of a scenario. The possible sequences of a simulation can be visually modeled as a *decision tree*: a diagram that includes all potential outcomes a teacher could experience based on their improvisational decisions (Figure 3). Modeling the consequences of a sequence of decisions allows the participant to study how power may be shaped over time via different sequences of decisions.

The improvisational decision-making moment can be made via either an audio recording or a button selection among two or more options, depending on the specificity of the response needed in relation to what the scripted students would say next. For instance, if a student says, “I need help,” a teacher’s first response will most likely not shift what the student would say next if they were determined to get a specific hint or answer. Therefore, in this case, we encourage pre-service teachers to improvise a realistic response sequence, so that they would get practice in responding to a common dilemma in a problem-solving setting (i.e., a student who continually pleads for support).

In cases where we wanted to allow for a pre-service teacher to improvise in a way that would lead to different outcomes within the simulation, we created a button selection where each choice offers the pre-service teacher with a specific prompt (such as “You decide to say, ‘What are the first numbers you need to add?’ versus asking a question). These choices not only provide later opportunities to recognize the consequences of particular instructional decisions; they also introduce pre-service teachers to possible actions that may not have occurred to them before.

Figure 3 – Decision Tree Model of Small Group within Digital Clinical Simulation



Design Principle #3: Connect to the Scale and Consequences of Decision-Making

As designers, we made predictions regarding what outcomes related to equity might look like in a particular moment in relation to the distribution of power. For example, although a choice of an instructional decision in a specific moment may seem to be supporting a student in accessing mathematical content (e.g., giving Gaby a hint because she asked for one so she can continue a task), continually making that choice over time may create a harmful dynamic for the student who is the recipient of that choice (e.g., feeding into Gaby's learned helplessness and never giving her an opportunity to try a problem on her own). In other words, the design of digital clinical simulations can enable a pre-service teacher to recognize that a choice that appears to be aligned with equitable mathematics teaching at a smaller scale can have a different effect when considered across a sequence of similar instructional decision-making moments. This complexity may be missed when focused on only one sequence of instructional decision-making. Designing with the entire set of possible paths in mind allowed us to think of potential takeaways depending on the experienced outcome within a particular scenario.

Although the example of interactions involving Group Two does not capture every nuance we considered in terms of maintaining cognitive demand, we did design outcomes that encompassed a range of potential student experiences that are critical for any pre-service teacher to think about regarding maintaining cognitive demand. The design tree reveals the ways that decisions over time are connected. For example, consider a pre-service teacher who only sees a single prompt, followed by a recorded response they gave, and a resulting prompt. The implication of their decision, with that perspective, may seem inconsequential. But it is possible to show the pre-service teacher the results of a sequence of decisions that connect to shifts of power: students continually asking for more detailed responses where the teacher lowers the cognitive demand accessible to them; students getting frustrated with a lack of support where the teacher does not attend to their emotional distress in an unsuccessful attempt to maintain access to cognitive demand; or students feeling supported to move forward with a particular choice that shifts power to students as opposed to another choice. Then there is an opportunity to consider new interpretations and choices in the series of moments. Instead of positioning improvisational responses as linked solely with the prompt at a particular moment, this design principle emphasizes how each prompt feeds into subsequent prompts: Incremental shifts in power dynamics depend on the decision a teacher makes at different moments in the simulation.

Furthermore, the design tree enables designers to conceptualize the multiple ways by which any sequence possible in the tree could be understood in a variety of ways. The designer not only has to consider decision-making pathways from the pre-service teacher's perspective, but also the array of ideological perspectives that a pre-service teacher could have used to support their choice to continue down a decision-making pathway. Even when our participants move forward to the same subsequent prompt, the reason for this advancement depends on their assumptions that fueled their initial response. That is, we posit that any decision made as potentially mobilized by different ideological perspectives and assumptions about students. We create the simulation knowing that the same or similar choice of instructional decision can be radically different depending on the ideological perspectives behind it, and revealing these nuances would happen during a post-simulation reflection. The design of the simulation creates an opportunity to specifically unravel how the same decision made by two different pre-service teachers may have been made with different ideological perspectives. Further, this process can be extrapolated to a sequence of choices.

Design Principles in Action: (De)Composing a Digital Clinical Simulation

Now, we will show how these design principles come together to create an effective experience for a pre-service teacher. We will go deeper into the design of decision-making regarding "Group 2", which focuses upon decisions related to maintaining a high level of cognitive demand. To do this, we will share the possible paths that the participants can take in the simulation, and how each path suggests ways in which a particular decision can change future responses by students within the simulation. Additionally, we will describe how each prompt that a pre-service teacher could encounter relates to larger design ideas regarding shifts in power between students and teachers, and cognitive demand.

Improvisational Moment: Recording Point 1

At the first moment within this small group, the pre-service teacher is informed they are checking in with three students (Ruth, Mason, and Gaby) and they are able to see that the students' papers are blank. Although it may seem that giving the students a hint would be a way for them to engage with the problem, viewing students with a perspective of equitable mathematics teaching would allow the pre-service teacher to realize that, even without anything written on the paper, the students have ideas to contribute. The pre-service teacher is prompted to respond to Gaby (Figure 3), [1] who says "I need help! I don't know where to start." At this moment, to potentially (re)distribute power, the pre-service teacher could ask what Ruth, Mason, and Gaby have thought about or noticed within the task; doing this would allow students to maintain the cognitive demand of the task, and for the teacher to make instructional decisions in relation to their authentic conceptions about the problem. The pre-service teacher could also ask the students to share their ideas in order to (re)distribute power among the three students themselves. Additionally, a pre-service teacher could recognize that the instinct for Gaby to ask for help does not necessarily mean she is requesting a step-by-step explanation; thus, a more equitable instructional move would balance providing Gaby some support through questioning but without removing the opportunity for her and the group to think through the problem.

Improvisational Moment: Decision Moment 1

Following the pre-service teacher responding verbally to the above, all pre-service teachers will be met with [2] Gaby responding with "Can you please just help me!" At this point, the pre-service teacher is prompted to either ask Gaby [Button A] "What are the first numbers you need to add?" or ask the students [Button B] "Well, Ruth and Mason, what do you think?". Button A serves as a leading question. Although it allows students to now share their thinking, it is taking away a significant portion of the cognitive demand from students because it is telling students what to do next. Button B allows students to share their thinking but does not necessarily address the root difficulty the group is experiencing with this particular choice.

If the pre-service teacher implicitly tells Gaby what two numbers to add via Button A, the simulation then leads the pre-service teacher to a response by [3] Mason, who says "Alright, yeah you are talking about 25 + 15. Thanks, Teach!" At this specific moment, the pre-service teacher in the simulation may feel that they provided a just-in-time intervention for students to engage in the task. However, Mason answering "for" Gaby shows a shift of power between the students, where Mason takes control of the conversation and provides a response to the teacher. Additionally, at this moment, [3] Ruth also says, "So we did that, now what else?" Looking at the sequence here, a pre-service teacher may have made these choices because they interpret the purpose of their instructional decisions to provide detailed support for the students to complete the problem. This might be one way to interpret Ruth's comment, where she immediately asks for further assistance instead of using the hint to engage with the problem themselves. If the pre-service teacher asks Ruth and Mason what they think [Button B], the pre-service teacher could be attempting to engage all voices within the group to try to surface other students' understanding of the task. In this case, the instructional decision involves an

attempt to attend to status and assumptions of student competence (i.e., the students are both given opportunities to actually share their thinking in a balanced way). The choice results in [4] Ruth saying, "We really don't know how to get started and need help," followed by Mason's response of, "yeah we really talked to each other and just need a hint because we are getting frustrated."

Improvisational Moment: Decision Moment 2a

Decision Moment 2a first arises for a pre-service teacher following their response of "what are the first numbers you need to add?" [Button A]. After choosing this, the simulation leads to [3] a comment by Mason that acknowledges the use of 25 and 15 regarding what numbers they need to add, with Ruth asking for the next step.

The pre-service teacher then has an option [Button C] of asking "Well, what do you need help with?" This specific choice may reflect the pre-service teacher trying to make space for the students to articulate an area of concern, potentially because the pre-service teacher believes it is equitable to create opportunities for open conversations about mathematics. This choice results in [5] Ruth saying "I don't know, why won't you just tell us? We still don't get it," with the teacher, as decided by the simulation, instructing the group to try drawing a picture of what is happening in the problem. First, this final decision is provided by the simulation in order to end the sequence and allow the teacher to have an opportunity to reflect on the sequence that led to this point. This sequence provides an opportunity for the pre-service teacher to recognize how, after choosing [Button A] to provide the students with a hint, the students in the group begin to expect continued support from the teacher even when the teacher tries to point students directly to where they are struggling [Button C]. This design highlights the mixed messages that we, as teachers, can give students, raising the question: should the teacher provide students with a detailed next step, or support them instead in further digesting the task, even though this may initially feel uncomfortable for students? When Ruth [5] responds with "why won't you just tell us," the simulation suggests that students can become frustrated when they come to expect very detailed support from teachers. However, by switching back and forth from heavy handed procedures to open questions, young people do not know what to expect (and what is expected of them) in the classroom (Benoit et al., 2025).

The pre-service teacher also has an option of asking "How many people with no siblings have a dog?" [Button D]. This specific choice functions similarly as [Button A] ("What are the first numbers you need to add?") by hinting at the way forward and eliminating the need for students to decide on the next step. In this chosen pathway, the pre-service teacher chooses to ask leading questions twice (first, [Button A], and [Button D]). Following choosing this option, [9] Ruth responds by saying "Cool, I think we got it from here, we will call you back when we are in need of more help." When a teacher asks successive closed, action-focused questions, students are able to continue with tasks independently. However, in terms of cognitive demand, continually giving such detailed hints means that there is not as much (or any) mathematical, computational, or meta-cognitive thinking required of the students. So, although the pre-service teacher may have chosen these hints to be equitable so students can begin the task, this sequence may not give students the opportunity to engage in much reasoning, strategy, or thinking, particularly if students are not given the opportunity to connect those numbers and procedures in the future.

Improvisational Moment: Decision Moment 2b

Decision Moment 2b arises for a pre-service teacher following their response [Button B] of "Well, Ruth and Mason, what do you think?" After making this choice, [4] Ruth reiterates that her group does not know how to get started, and Mason admits that they are getting frustrated without a hint.

The pre-service teacher then has the option [Button E] of asking "What are the first numbers you need to add?" After choosing this, the simulation leads to [5] the same response as if a pre-service teacher chose [Button A] to ask about the numbers to add followed by [Button C] asking where they specifically needed help, i.e. Ruth asks for a more specific hint. This specific sequence reiterates that, even by starting with a more open question, when the pre-service teacher then specifically asks students which numbers they should add, it leads to the same type of response as when the pre-service teacher just offered to give a more specific hint from the start. As designers, the "conclusion" of these paths being the same emphasizes the importance of a teacher being consistent to avoid undermining early attempts to maintain the cognitive demand. Note that the way power dynamics are interpreted in the "conclusion" depends on the sequence of choices, where the final choice can contribute to different interpretations of the conclusion.

The pre-service teacher is also given the option to ask a question [Button F], leading to [6] Mason to explicitly ask for another hint. In the sequence of asking Ruth and Mason to share their thinking [Button B], and then continuing to ask questions [Button F], here the pre-service teacher is consistently trying to maintain the cognitive demand through questions that orient students to parts of the problem while maintaining cognitive demand.

Improvisational Moment: Recording Point 2

Recording Point 2 asks the pre-service teacher to respond to Mason asking for another hint [6]. After two decision points where the pre-service teacher has asked questions that maintain students' access to cognitive demand [Button B, Button F], the simulation leads to [7] Ruth and Gaby pushing the teacher to provide a more specific hint. As designers, the continual resistance from students in asking the teacher to provide a hint begins to tease out the complexity of encouraging students to take responsibility for their own thinking — does the teacher, despite students asking for a hint, continue to stay true to their attempts to support student autonomy? What could a teacher say at this moment that not only acknowledges the students' frustration but also does not shy away from taking students' opportunity to problem solve from them? To enable an opportunity for the pre-service teacher to engage with this challenge, the simulation at this point prompts an auditory response to be recorded.

Improvisational Moment: Decision Moment 3

The final decision moment in this scenario is in response to [7] Ruth and Gaby saying "Well that wasn't helpful. Can you just tell us how to get started?"

The first choice here [Button G] involves asking the students for the first numbers they need to add. This response leads the simulation back to [5] Ruth again asking for a hint. Despite trying to make instructional decisions that are equitable, the pre-service teacher's final choice [Button G] to ask a very specific question shows a shift in strategy. This shift may make students infer that, as long as they keep asking for specific help, they do not

need to do any of the thinking because the teacher will eventually give them a specific hint. Although a similar construct to the decision a pre-service teacher made earlier, it is significant to orient pre-service teachers to the fact that they may change their choice of instructional decision when students are not responding in the way the pre-service teacher anticipated.

The second choice [Button H] assumes the teacher wants to make a response other than "What are the first numbers you need to add?" [Button G]. Following this choice, [8] Mason says that he and his group will talk through that final response. This sequence highlights the importance of a teacher consistently not asking leading questions.

Affordances and Limitations

Designing a simulation creates an opportunity for educational designers to anticipate how pre-service teachers may improvise within a *sequence of instructional decision-making*, particularly where a pre-service teacher may feel tension about the ways that their choice supports or undermines equitable mathematics teaching. Our design principles describe how digital clinical simulations can allow pre-service teachers to practice improvising instructional decisions within multiple small, prompted moments and to reflect on how their assumptions influenced students' experiences. Improvisation, therefore, lets pre-service teachers rehearse learned instructional decisions in a context with design details that provide clarity in aspects such as mathematical tasks and student discourse but ambiguity in terms of students' prior experiences, leaving room for assumptions. Further, reflecting on sequences of decision-making can further enable pre-service teachers to recognize the variety of ways by which a particular series of improvised decisions may have consequences in relation to students' learning. Here, power dynamics, as part of those decisions, either make mathematical learning more or less accessible for students most marginalized in the mathematics classroom.

Despite these benefits, these digital clinical simulations do not currently allow the pre-service teacher to engage in the practice of forming interpersonal relations. This limitation is especially important as a critical component of equity work is reconceptualizing and shifting power within any interpersonal relationship. Although digital clinical simulations can create opportunities to practice instructional decisions that attend to equity, it is difficult to fully simulate the nuanced relationship that occurs between teachers and students, and between students themselves. Additionally, the simulation can take complex moments and isolate them, limiting a teacher's ability to make connections with a student's histories and experiences in the classroom when making specific decisions. There is evidence that the moments before and after a given simulation have the potential to impact a particular instructional decision, or interpretation of the instructional decision that happens, in the classroom. For example, if a student who does not regularly speak or contributes in a mathematics classroom happens to raise their hand and seems to take a lot of conversational space, a teacher would recognize the importance of recognizing their voice in that moment (Self & Stengel, 2020). Because of this, simulations that are designed to attend to equity will not fully encompass the complexity of practice that arises in real classrooms with real young people. In other words, simulations cannot model the totality of a students' histories and background within a moment of simulated practice.

Additionally, we acknowledge the inherent tensions between when a teacher's "consistency" is rewarded at one moment, while at another, it can mean a teacher may have removed access to the task's cognitive demand. Although this may be frustrating or feel like a guessing game in terms of our design intentions, this tension points to the inherent complexity of how power dynamics may or may not emerge in the mathematics classroom. This is particularly the case when thinking of the relationship between power dynamics and instructional decisions such as the type of questions asked and how those questions enable or remove access to the cognitive demand of the task.

Therefore, because of these limitations, it is critical to pair the use of digital clinical simulations with an intentionally designed debrief to attend to what cannot be represented in the simulation (e.g., a history with the students in the simulation, physical proximity to the students, tone and emotional signals from the students and within the teacher's responses). Facets of power both shape the teacher's ideological perspectives, their perception of events in a situated context, and subsequent choices alongside student's responses (i.e., learned helplessness). Therefore, digital clinical simulations benefit from debrief discussions focused on students' power as it is shaped by a teacher's use of instructional choice and ideological perspective as to why they made that choice (see Barno, 2025b).

Consider, for instance, two different pre-service teachers who both select Button A. Within one seemingly singular path, each teacher who has chosen that path has a set of ideological perspectives that has impacted these decisions. Mathematics teacher educators must be prepared to engage pre-service teachers in how the digital clinical simulation design can be understood, with multiple interpretations of how each path of a decision tree could be taken up, asking questions such as *How did your choice position students within the small group?* and *How could a different choice position students in a different way, or under what contexts would that choice be best for students' learning?* That way, pre-service teachers can discuss their own interpretations of what the simulated students said, describe why they made their own improvisational response within the simulation, and begin to move towards a deeper understanding of equitable mathematics teaching.

Discussion

Digital clinical simulations enable pre-service teachers to try out instructional decisions without needing to directly interact with students. The flexibility of digital clinical simulations allows the exploration of different instructional decisions, providing a relevant experience that considers the way in which equity (and inequity) may function within the mathematics classroom. Further, simulations afford designers the opportunity to create a wider variety of situations than those that may occur during pre-service teacher field placement settings. Put differently, digital clinical simulations offer mathematics teacher educators the opportunity to design critical decision moments that could sharpen pre-service teacher learning about equitable mathematics teaching. Rather than hoping that pre-service teachers encounter an opportunity to practice and reflect about equity in a way that complicates how power shapes classroom decisions and interactions, we can design to create the opportunity.

As we have shown, educational designers can help to draw attention to the ways that the choice of an instructional decision is influenced by a teacher's ideological perspectives and perception of what is going on within moments and across sequences of decisions. Designing choices of instructional decisions at decision points, as well as decision paths through the simulation, requires designers to consider the multiple possible ideological

perspectives that may influence a decision at a particular moment. Additionally, designers of digital clinical simulations need to pay attention to the relationship between the moment a decision is made and the ways that this decision may relate to a sequential path of decisions. For this goal, it is important to debrief after the experience to better understand pre-service teacher decision-making, its possible influences, and its implications.

Aligning with critiques of practice-based education, we do not believe a digital clinical simulation should involve practicing only one specific instructional choice (such as pre-scripted phrases that a teacher can say in a classroom to facilitate discussion or encourage student thinking). And although classrooms are complicated places, we do feel there is value in practicing decision-making among multiple possible choices within digital clinical simulations. By reflecting on the range of potential responses across different moments, such a simulation design allows pre-service teachers not only to reflect on their own instructional decision at a particular moment, but also to consider a variety of other instructional decisions to make within other moments. Pre-service teachers, therefore, can walk away from a simulation experience with a layered understanding of their own choice, but also of other choices to use within different moments.

Equitable approaches in mathematics education attempt to move teaching and learning away from inequitable deficit perspectives that seem to only acknowledge and value a few students (Coleman et al., 2017). While the field has made a concerted effort in forging a path toward equitable teaching and learning (Hammond, 2014; Gutiérrez, 2018), there is still a need to build our understanding to operationalize instructional practices and other teacher education efforts that support more equitable learning experiences for every student (NCTM Research Committee, 2018). Even when educators know *what to say* and can articulate definitions and examples of equitable mathematics teaching, they often have difficulties knowing *what to do* when faced with common dilemmas in a classroom with real students. Designers, therefore, are in a powerful position to create practice opportunities to discuss the relationship between instructional decisions and the ideological perspectives that influence them in relation to inequitable experiences for young people. By creating digital clinical simulations that carefully surface these complexities, we hope designers can leverage their ability to craft scenarios that allow pre-service teachers to try out and unpack complexities about power in the classroom and be prepared to face such complexities when they enter the classroom.

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