Research Memorandum
ETS RM–21-10

Conceptualization and Development of a Performance Task for Assessing and Building Elementary Preservice Teachers' Ability to Facilitate Argumentation-Focused Discussions in Mathematics: The Ordering Fractions Task

Heather Howell
Jamie N. Mikeska
Jessica Tierney
Benjamin Baehr
Penny Lehman

December 2021

ETS Research Memorandum Series

Conceptualization and Development of a Performance Task for Assessing and Building Elementary Preservice Teachers' Ability to Facilitate Argumentation-Focused Discussions in Mathematics: The Ordering Fractions Task

Heather Howell, Jamie N. Mikeska, Jessica Tierney, & Benjamin Baehr
ETS, Princeton, New Jersey, United States

Penny Lehman
Consultant

December 2021

Corresponding author: H. Howell, E-mail: hhowell@ets.org

Suggested citation: Howell, H., Mikeska, J. N., Tierney, J., Baehr, B., & Lehman, P. (2021). *Conceptualization and development of a performance task for assessing and building elementary preservice teachers' ability to facilitate argumentation-focused discussions in mathematics: The Ordering Fractions task* (Research Memorandum No. RM-21-10). ETS.

Action Editors: John Mazzeo and Laura Hamilton

Reviewers: Dante Cisterna-Alburquerque and Gabrielle Cayton-Hodges

Abstract

In this research memorandum, one of a series of eight such reports, we describe the development process by which we produced a series of performance tasks designed for preservice elementary teachers for formative assessment use in the context of teacher education programs. Each performance task provides an opportunity for preservice elementary teachers to practice facilitating an argumentation-focused discussion targeting a student learning goal in elementary mathematics or science. One unique aspect of this work is that the discussions take place within an online simulated classroom environment that consists of five upper elementary student avatars. This report documents the development process at three levels. First, we define the overarching teaching competency that each task targets—the ability to facilitate argumentation-focused discussions—by describing the general approach and processes used to develop the full set of eight tasks and the key components embedded within each task. Next, we describe the academic content addressed in the subset of four mathematics tasks and how the content conceptualization supports the use of the tasks individually or as a set. We then discuss the specific task that is the focus of this research memorandum, outlining how it was designed to capture evidence of the targeted teaching competency.

Keywords: performance task, elementary education, simulated classrooms, virtual reality, discussion, argumentation, preservice teachers, teacher education, mathematics, fractions

Acknowledgments

This study was supported by a grant from the National Science Foundation (Award No. 1621344). The opinions expressed herein are those of the authors and not the funding agency.

The development of these performance tasks, especially the interactor training materials, was enhanced by the feedback from the talented group of Mursion interactors who worked on this project and who served as the human in the loop during these simulated discussions. In addition, we are grateful for the advice and critical review of these tasks from our advisory board members, assessment developers, and research colleagues. Finally, we are appreciative of the teacher educators and preservice teachers who provided substantive feedback on how to improve these tasks for future use in teacher education.

Preface

This research memorandum is one of eight reports in which we describe the development process by which we produced a series of performance tasks designed for preservice elementary teachers for formative assessment use in the context of teacher education programs. The following table provides an overview of the eight performance tasks.

Descriptions of the Eight Performance Tasks

Task name	Task description
	Mathematics
Ordering Fractions	The teacher leads a discussion of three student-generated strategies for ordering a set of given fractions from least to greatest.
Fractions Between	The teacher leads a discussion with the students about an unconventional student-generated method for generating fractions between two given fractions. The discussion is focused on the strengths and weaknesses of the strategy, and its applicability to other situations.
Birdseed	This discussion is grounded in students' work on a story problem in which they have used fraction multiplication. Prior to the discussion, the students individually critiqued one another's work, making the critique aspect of argumentation more clearly available to the teacher.
Eight Divided by One Fourth	This discussion focuses on students' work to generate meaningful understandings and representations of division by a fraction.
	Science
Mystery Powder	This discussion focuses on reaching group consensus around the identity of an unknown powder based on its properties and what is known about a set of common powders. In addition to identifying the mystery powder, students discuss which properties are most useful and why.
Conservation of Matter	In this task, the teacher supports the students in discussing whether the amount of matter is conserved during a physical change, in this case the mixing of ingredients to produce lemonade.
Modeling Matter	This task focuses on critiquing and revising visual models for explaining what happens after a drop of red food coloring is dropped into a cup of water.
Changing Matter	This discussion builds on students' prior work mixing together different combinations of substances and forming claims about whether each combination produced a new substance, with an emphasis on using evidence to support those claims.

Each report is dedicated to a singular task and provides a full description and corresponding appendix text for that particular task. All of the reports include a description of the general development process that applies to the full set of tasks. Additional materials to support the use of the performance tasks, such as interactor training and scoring documentation, are not included in these reports but are archived and publicly available through the Qualitative Data Repository housed at Syracuse University (https://data.qdr.syr.edu/dataverse/go-discuss).

The first section of this report details the development of the performance tasks, including a description of the construct, the task type, and the process used to develop each of the eight tasks. In the second section, we discuss the content focus of the set of mathematics tasks and of the Ordering Fractions task in particular. In the final section, we describe the resulting set of materials that make up the stable components of the task itself and use examples from the Ordering Fractions task to illustrate what these components look like and how they function together in the performance task.

Section 1: Development of the Performance Tasks

In this section of the report, we share our conceptualization of the teaching practice of facilitating argumentation-focused discussions, describe what a simulated teaching performance task is, and explain how our use of the performance task maps onto the conceptualization of the teaching practice. We finish by outlining the process steps that we used to develop the tasks.

Construct Definition: Facilitating Argumentation-Focused Discussions

Our construct of interest is the teaching practice of facilitating discussions that engage students in argumentation, or what we refer to as "facilitating argumentation-focused discussions." We focused on this teaching practice for a number of reasons. First, facilitating argumentation-focused discussions is an ambitious teaching practice that is critically important for teachers to learn how to do well in order to support student conceptual learning within content areas (Kazemi & Stipek, 2009; Russell et al., 2017; Stylianides et al., 2016; Walshaw & Anthony, 2008). Second, this practice is hard to learn how to do well, and many teachers—even experienced teachers—tend to have had little opportunity to learn how to do well (Barkai et al., 2002; Reid & Zack, 2009). Finally, the focus on argumentation was purposeful. Although teachers may facilitate many kinds of discussions with K–12 students, both the *Common Core State Standards* and *Next Generation Science Standards* (National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010; National Research Council, 2013) identify argumentation as one of the key mathematical and scientific practices that K–12 students need to master.

To define the construct that we were aiming to measure—preservice elementary teachers' ability to facilitate argumentation-focused discussions—we began by reviewing the empirical and practitioner literature as well as the current student standards in mathematics and science to identify the core aspects of this teaching practice. Building on this review, we identified five dimensions of high-quality, argumentation-focused discussions: (a) attending to students' ideas, (b) developing a coherent and connected storyline, (c) encouraging student-to-student interactions, (d) developing students' conceptual understanding, and (e) engaging students in argumentation. Table 1 provides details about the specific focus of each dimension.

Table 1. Dimensions of a Scoring Rubric to Evaluate Preservice Teachers' Ability to Facilitate Argumentation-Focused Discussions

Dimension	Description: Degree to which the teacher. . .
Attending to students' ideas	. . . is being responsive to students, with a focus on making sure the discussion is grounded in the ideas the students bring with them
Developing a coherent and connected storyline	. . . is able to shape a coherent discussion, with a focus on building and connecting ideas toward an instructional goal
Encouraging student-to-student interactions	. . . organizes the classroom community and the social interactions so students respond directly to one another's thinking
Developing students' conceptual understanding	. . . makes productive decisions about how to address particular ideas, especially students' misunderstandings
Engaging students in argumentation	. . . emphasizes disciplinary argumentation (e.g., consideration of opposing claims; facilitates critique and rebuttals; encourages students to draw upon evidence and reasoning)

Note. Adapted from "Using Performance Tasks Within Simulated Environments to Assess Teachers' Ability to Engage in Coordinated, Accumulated, and Dynamic (CAD) Competencies" by J. N. Mikeska, H. Howell, and C. Straub, 2019, *International Journal of Testing, 19*(2), p. 138 (https://doi.org/10.1080/15305058.2018.1551223). Copyright 2019 by Taylor & Francis.

The first dimension, attending to students' ideas, focuses on the extent to which teachers are responsive to students' ideas in equitable ways, ensuring that the discussion is grounded in students' ideas and that all students are engaged in meaningful aspects of the discussion. The second dimension, developing a coherent and connected storyline, targets the degree to which the teacher can shape a coherent discussion by building and connecting ideas toward a learning goal. The third dimension, encouraging student-to-student interactions, emphasizes how teachers facilitate the discussion so students are the ones responsible for interacting directly with each other and engaging with one another's ideas. The fourth dimension, developing students' conceptual understanding, targets the extent to which the teacher and students are involved in evaluating the accuracy and validity of key ideas and how well the teacher productively addresses students' misunderstandings. The fifth dimension, engaging students in argumentation, emphasizes the degree to which students are invited to and engage in argument construction and critique during the discussion.

Simulated Teaching Performance Tasks

The overall goal of our research was to develop a set of simulation-based performance tasks that could be used to assess and build preservice elementary teachers' ability to facilitate argumentation-focused discussions. We conducted this work in the context of an innovative, mixed reality platform (see Figure 1)—an upper elementary simulated classroom composed of five student avatars.

Figure 1. Image of an Upper Elementary Simulated Classroom

Credit: Image courtesy of Mursion

The student avatars are controlled on the back end by a human in the loop, called an *interactor*, who is trained to respond as each of the five student avatars during the discussion. The preservice teacher does not see the interactor but instead views the student avatars on a television or computer screen and can interact with the student avatars in real time during the discussion. We hypothesized that the simulated classroom could serve as a practice-based space for preservice teachers to hone their skill in this teaching competency. Each performance task was designed to be deployed within the upper elementary classroom environment.

The teaching competency of facilitating argumentation-focused discussions is one that involves complex interactions between a teacher and students around specified content. It requires a practice space that provides opportunities for extended interactions to unfold over time, as a teacher's ability to engage in this practice is observable only across these patterns of interactions (Mikeska et al., 2019). In earlier writing, we describe this competency as one that is "coordinated," "accumulated," and "dynamic" (Mikeska et al., 2019, pp. 132–133). By *coordinated*, we mean that the teacher is required to manage multiple, sometimes competing, considerations simultaneously—for example, trying to balance the goal of engaging students in argumentation with addressing students' erroneous conceptual understanding. *Accumulated* refers to the nature of the evidence that needs to be captured, as the teaching competency is observed over time across the patterns of interactions and not by examining individual, disparate interactions. By *dynamic*, we mean that this teaching competency is observed as teachers respond to the constantly changing nature of various task conditions. Each one of these aspects has implications for task design.

First, to ensure that we were adequately measuring this teaching competency, we had to ensure that our task design afforded teachers the opportunity to manage various considerations at the same time. Second, we had to ensure that the tasks provided substantial opportunities to capture evidence at various time points. For example, the tasks needed to provide us opportunity to observe how teachers prompt (or fail to prompt) direct student dialogue and the ways that students begin to engage in specific behaviors more (or less) frequently based on this teacher prompting over time. Finally, we had to create variable task situations so that the teacher would be required to respond to the changing nature of the situation over time, for example, creating dynamic student profiles where students can "learn" based on their interactions with other students and the teacher, as described in the final section of this report. In the next section, we explain our process for developing each performance task, which includes both the preservice teacher–facing task materials and the interactor-facing task materials.

Overview of the Task Design Process

Because the overall goal of using these tasks was to be able to make valid inferences about preservice teachers' ability to facilitate discussions that engage students in the practice of argumentation, we drew upon the process of evidence-centered design (Mislevy et al., 2002) to develop our evidence model. We then used this evidence model to inform the overall design of each performance task. Our first step was to use our construct definition to develop an evidence model to articulate the observable behaviors that could serve as evidence of preservice teachers' ability to engage successfully in each dimension. For example, for the first dimension—attending to students' ideas—we identified three indicators of that dimension of this overall teaching practice, including the preservice teachers' abilities to incorporate ideas from the students' written prework into the discussion, to elicit substantive ideas from all students, and to make use of students' ideas to move the lesson forward in regard to the discussion's specified student learning goal. We further elaborated each one at three levels of proficiency—beginning novice, developing novice, and well-prepared novice—to describe the observable behaviors one would gather evidence about to inform assessment of that indicator. For example, for the previously discussed dimension, attending to students' ideas, under the second indicator, eliciting substantive ideas, the observable behaviors specified (Figure 2) indicate that elicitation of substantive ideas from students is related both to the teacher's sustained efforts to elicit such contributions and to the teacher's success in eliciting such contributions from all students. Substantive ideas are defined as those that go beyond yes/no statements or restatements of the work the student completed before the discussion.

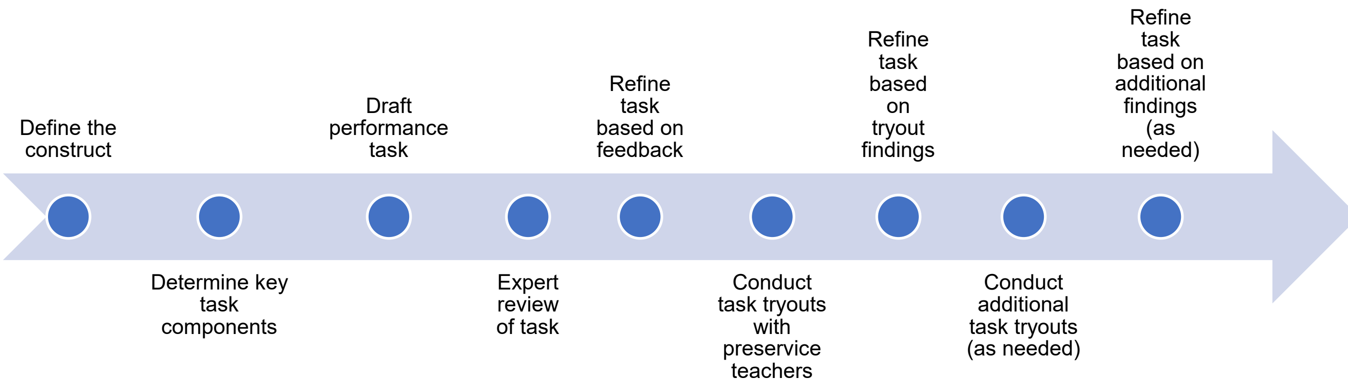
Figure 2. Example of Observable Behaviors for Indicator 1b: Elicits Substantive Contributions

Indicator	Level 1 Beginning Novice	Level 2 Developing Novice	Level 3 Well-Prepared Novice
1b. **Elicits Substantive Contributions**	The teacher does not probe students for substantive contributions or does so only once or twice. OR The teacher interacts with only one student from each group.	The teacher probes students for substantive contributions intermittently during the lesson. AND The teacher does not elicit a substantive contribution from at least one student.	The teacher probes students for substantive contributions consistently throughout the lesson. AND The teacher succeeds in eliciting one or more substantive contribution from **every** student.

Our project's advisory board, made up of teacher educators, content specialists, and researchers in mathematics and science teacher education, conducted an expert review of these dimensions and indicators. Their goal was, first, to ensure that they were adequately aligned to the construct and previous literature in mathematics and science teacher education and, second, to provide feedback on whether our characterization of high-quality discussions in the context of disciplinary argumentation adequately addressed the ways in which this teaching practice is used, valued, and characterized within each of the disciplines (elementary mathematics and science). The advisory board also identified and offered suggestions for any aspects of our construct definition that were missing, misrepresented, or not sufficiently addressed. Finally, they considered whether the progressions seemed logical, comprehensive, and scoreable and captured the most important observable teacher behaviors for each dimension and indicator.

In the design of the performance tasks themselves, we used a design-based research approach (Design-Based Research Collective, 2003) in developing and refining the task materials[1] at multiple stages and leveraging various expertise from teacher educators, researchers, preservice and in-service teachers, content experts, and assessment developers (Figure 3). After defining the construct of interest, including the specific dimensions and indicators of this teaching practice, the next step in our task design process was to determine the key task components that would provide opportunities for the preservice teachers to engage in these dimensions of this teaching practice and support us in capturing adequate evidence across all five dimensions.

Figure 3. Progression of the Design-Based Research Process



The task materials include two types of components: the preservice teacher–facing and the interactor training materials. The preservice teacher–facing materials include a written document that provides information to the preservice teacher about the simulated discussion's student learning goal, where this discussion fits into a larger instructional sequence, and what the instructional activities are that the student avatars engaged in prior to this discussion. This document also shows the preservice teacher written work samples that the student avatars generated prior to the discussion, which provides the preservice teachers with insight into the students' sense-making about the specific mathematics problem or science investigation that is the focus of the discussion. In addition, we developed materials to train the interactor. These training materials are designed to help the interactor learn about the student avatars' initial ideas and understandings related to the mathematics problem or science investigation that is the focus for the discussion. These materials also support the interactor in learning about the circumstances under which the student avatars can arrive at new understandings based on ideas and arguments that the preservice teacher or the other students make during the discussion. This level of training is also critical in helping to support the standardization of opportunity across preservice teachers so that experiences in the simulated classroom are comparable in the level and nature of challenge each preservice teacher encounters (Howell & Mikeska, 2021). We describe specific components for these task materials, including how we designed them to capture adequate evidence of the five dimensions of this teaching competency, in the final section of this manuscript.

The next step in our task development process included an expert review of the performance task materials to ensure that the task components (both preservice teacher and interactor facing) worked synergistically to gather observable evidence of the preservice teachers' ability to facilitate argumentation-focused discussions. Reviewers included our advisory board members and assessment development experts, who reviewed the preservice teacher–facing materials to ensure that (a) the task provided opportunities for the preservice teachers to engage the student avatars in the practice of mathematical or scientific argumentation; (b) the written student work samples captured a range of typical responses for upper elementary students regarding the specific mathematics problem or science investigation that was the focus of the discussion; and (c) the educative features in the task would be useful to support preservice elementary teachers in learning how to facilitate high-quality, argumentation-focused discussions centered around these student learning goals. Reviewers also considered whether each of the preservice teacher–facing task components—such as the student learning goal, specific instructional scenario, task description, and student profiles—were clear, appropriate, and sufficient for the intended audience. In terms of the interactor training materials, reviewers focused on ensuring that we identified reasonable responses for the interactor to use as the discussion unfolds in the simulated classroom and that the responses did not limit or misrepresent the preservice teachers' ability to engage in this teaching practice. Our research team then revised these task materials based on the experts' feedback. These revisions included a variety of different changes across these tasks, such as more clearly articulating the discussion's student learning goal, modifying the written student responses to better align with grade-level expectations, refining the teaching tips to provide more robust educative supports for the preservice teachers, and updating the lesson overview and background sections to ensure that the preservice teachers understood where they were being dropped into a larger instructional sequence.

Once we had developed task materials that we hypothesized would allow us to make valid inferences about preservice teachers' ability to facilitate argumentation-focused discussions, we then engaged in a set of tryouts for each performance task. For each tryout, we recruited five to 10 preservice teachers to pilot the task with us within the simulated classroom.

Prior to each tryout, our research team trained interactors on how to enact the student avatars' responses in alignment with the student thinking profiles developed for each task. During the interactor training, we systematically gathered additional information to inform revisions of those materials, assigning a team member as a dedicated observer for each section of training to document where the interactors needed additional support.

For the tryouts, each participating preservice teacher reviewed the preservice teacher–facing task document to prepare for their simulated discussion and then facilitated a discussion for up to 20 minutes with the five student avatars in the simulated classroom. Our research team video recorded these discussions and later scored each one based on the scoring rubric we had developed from the five dimensions of our construct and the progression levels for each dimension. We also gathered self-reported data from each preservice teacher via a task survey and semistructured interview to learn about their perceptions of the task authenticity, interactions with the student avatars, their discussion performance, and the usefulness of the simulated teaching experience integrated within mathematics and science elementary method courses. Our research team analyzed these data sources to identify patterns in the preservice teachers' perceptions of these task materials and their discussion performances and then used the tryout findings to refine the task materials and our scoring rubric further.

These revisions, like those that took place after expert review, included attention to the clarity of wording throughout the preservice teacher–facing materials, which involved simplifying wording and presentation, refining the teaching tips to call attention to points that had been misunderstood, and in a few cases, revising the core content of the task to better fit the 20-minute time limit. We also revised interactor training materials to provide more support in areas that we had observed to be difficult and to refine language where we had observed it to be confusing to one or more interactors during training. For four of the eight tasks, the resulting revisions were substantial enough to warrant a second round of tryouts using a similar process of data collection, analysis, and task refinement.

Once we finalized the task materials and scoring rubric based on the tryout findings, we then used them in the research project's main study within multiple sections of elementary mathematics and science courses at three different universities in the United States.

Section 2: Content Focus of the Performance Tasks

Each set of performance tasks in mathematics or science is grounded in a single *high-leverage content area*, which, as described in Martin-Raugh et al. (2016), is operationalized following the model of Ball and Forzani's (2011) high-leverage practice framework to include content of the student curriculum that is foundational, spans multiple grade levels, and makes up a significant component of the student curriculum and in which students often struggle absent strong instruction. In other words, it is the content that is most consequential for students to learn well and, therefore, most important for teachers to teach skillfully. In science, the content area of focus is matter and its interactions; in mathematics, the content area of focus is fractions and operations with fractions.

Content Focus of the Math Tasks

In 2016, Martin-Raugh et al. identified fractions and operations with fractions as one of the high-leverage content topics within the elementary mathematics curriculum via a systematic analysis of the mathematics content of the Common Core State Standards. Research has widely acknowledged that factions and operations with fractions is a difficult for teachers to learn how to teach; however, there exists a broad empirical research base on which to model common student understandings and misunderstandings (Ball, 1993; Lamon, 2012; Newton, 2008).

One goal of this focus on high-leverage content was to create a coherent and connected set of performance tasks that would fit together across the time span of a semester, make sense in sequence, and include core content that teacher educators likely would have made a focus of instruction in their work with preservice elementary teachers. Within the set of mathematics performance tasks, the Fractions Between, Birdseed, and Eight Divided by One Fourth tasks were designed to be presented in order across the semester, as this was our envisioned use case, while still standing alone if later used individually outside of a sequence. Fractions Between focuses on a student-generated method for identifying fractions between two given fractions and deciding whether that method is valid and generalizable. The Birdseed task is organized around student solutions to a given word problem for which an area model is used to represent the multiplication of fractions in finding a solution. The Eight Divided by One

Fourth task is grounded in the question of what it means to divide by a fraction and presupposes that it is the student avatars' first exposure to fraction division.

This ordering of ideas met two prespecified criteria. First, this sequence allows the student avatars to appear to advance through a typical mathematics instructional sequence by moving from a focus on considering strategies for identifying fractions between two given fractions to then considering various operations (multiplying and then dividing) with fractions. Second, the specific mathematics of each task does not depend directly on the mathematics of the prior task, minimizing instances where a preservice teacher might expect a particular student avatar to remember the exact content of the prior task. The Ordering Fractions performance task, unlike the others, was designed to be used as a pre and post measure at the beginning and end of an elementary methods course and therefore needed to be conceptualized such that it would be reasonable for preservice teachers to engage in before and after the other three tasks. Fraction comparison is a topic that teachers often return to at different points of the curriculum and in which students can engage with different levels of sophistication across multiple grades, making it a good fit to this purpose. The Fractions Between, Birdseed, and Eight Divided by One Fourth tasks are described in detail in other reports in this series. In the following section, we describe in more detail the Ordering Fractions task, which is the focus of this report.

The Ordering Fractions Mathematics Task

The Ordering Fractions performance task is focused on comparing different student-generated strategies for ordering a set of three given fractions—3/10, 9/10, and 3/4—from least to greatest. The preservice teacher is provided a packet of materials (the preservice teacher–facing materials) prior to facilitating the discussion in the simulated classroom following a template used across the full set of tasks. The packet describes the work that five students have already completed on the mathematics problem, including showing written work from each student or group of students. For this particular task, one of the students, Mina, has worked alone, and the other four have worked in two pairs, with Will and Jayla working together and Emily and Carlos working together. Mina used whole number reasoning to arrive at an answer that is not correct, evincing a typical student misconception. Will and Jayla used a number line approach to order the fractions correctly, but their claim that the method will always work is complicated. In theory, such a method always works, but practically speaking, it can be difficult to execute. Emily and Carlos, the last group, used a method that combines several strategies to successfully order the three fractions. Each strategy is valid but might not always be useful for solving such problems. This intentional variation across the three groups provides opportunities for the preservice teacher to guide the students in critiquing and comparing the methods, to elicit justifications for their claims of generality, and to guide them toward consensus about both the correct ordering of the fractions and their conclusions around the generalizability of the strategies.

Section 3: The Generalized Task Design

As referenced previously, one of the outcomes of the design-based research process described in the first section was the development of a stable set of task components to be used across all eight (four science and four mathematics) tasks and designed to support a consistent experience for preservice teachers. The resulting template can be used to support future development by providing a structure for newly developed tasks with different content and is described here in the context of the Ordering Fractions task.

Each task is made up of two types of components: the preservice teacher–facing materials and the interactor training materials. Table 2 lists the task components of the preservice teacher–facing materials, which includes three documents for each task. The Introduction to the Simulated Classroom and the Warm-Up Task are separate handouts that are used in common across all eight performance tasks and provide an overview of how the simulation works and a brief familiarization exercise to get the preservice teacher started before they lead the discussion. The main document is the performance task itself (see the appendix for the full text of the Ordering Fractions performance task), which is designed to help the preservice teacher plan for and lead the discussion. Task components in the preservice teacher–facing task document include the sections Introduction to the Task, Lesson Overview, Student Responses, Making Sense of the Student Work, Shared Workspace Pages, Features of High-Quality Discussions Focused on Argumentation, and Video Examples of High-Quality

Discussions Focused on Argumentation. Teaching tips appear throughout the document rather than as a separate section.

Table 2. Components of the Preservice Teacher–Facing Task Materials

Component	Purpose
Introduction to the Simulated Classroom (separate handout)	This stand-alone handout acquaints the preservice teacher with the basic functionality of the simulated classroom as well as introduces them to each of the five students via short bios. It also includes links to short videos in which the students introduce themselves.
The Warm-Up Task: Taking the Students' Lunch Orders (separate handout)	The warm-up task, which takes about 5 minutes, is a scripted task in which the preservice teacher takes the students' lunch orders. It is intended to allow the preservice teacher to become accustomed with the simulated environment before starting the discussion.
Introduction to the Task	This task component orients the preservice teacher to the task. It includes a clear statement of the student learning goal and what the preservice teachers should aim to do during the discussion.
Lesson Overview	This task component situates the 20-minute discussion within the larger lesson and instructional sequence, describing students' background knowledge as well as what transpired in the class before the discussion began.
Student Responses	This task component provides each student group's written work, which was generated prior to the discussion.
Making Sense of the Student Work	This task component complements the student responses and provides explanatory text to help the preservice teacher understand the students' written work. The explanatory text identifies salient features of the students' ideas that might inform the discussion.
Shared Workspace Pages	This task component includes copies of the written student work and any other relevant reference material (e.g., class data table). It can be printed out for use during the discussion.

Component	Purpose
Features of High-Quality Discussions Focused on Argumentation	This task component is a short list of the key features of high-quality discussions as we have defined them and includes a set of questions about each feature. The preservice teacher can use the questions before or after the discussion to support them in considering how well their discussion will or did meet the task's specified student learning goal.
Video Examples of High-Quality Discussions Focused on Argumentation	This task component provides links to publicly available examples of classroom discussions that illustrate some of the features of high-quality argumentation-focused discussions. The preservice teacher can use the examples to better understand these features and how to incorporate them into their discussion.
Teaching Tips	This task component is embedded throughout the preservice teacher–facing materials and includes teaching tip bubbles that call attention to important ideas about how the discussion might be planned and enacted.

Table 3 lists the components of the interactor training materials, including a series of lessons that combine self-study modules with planned interactive practice with a content expert or trainer in order to help the interactor master the delivery of the task in the simulated classroom.

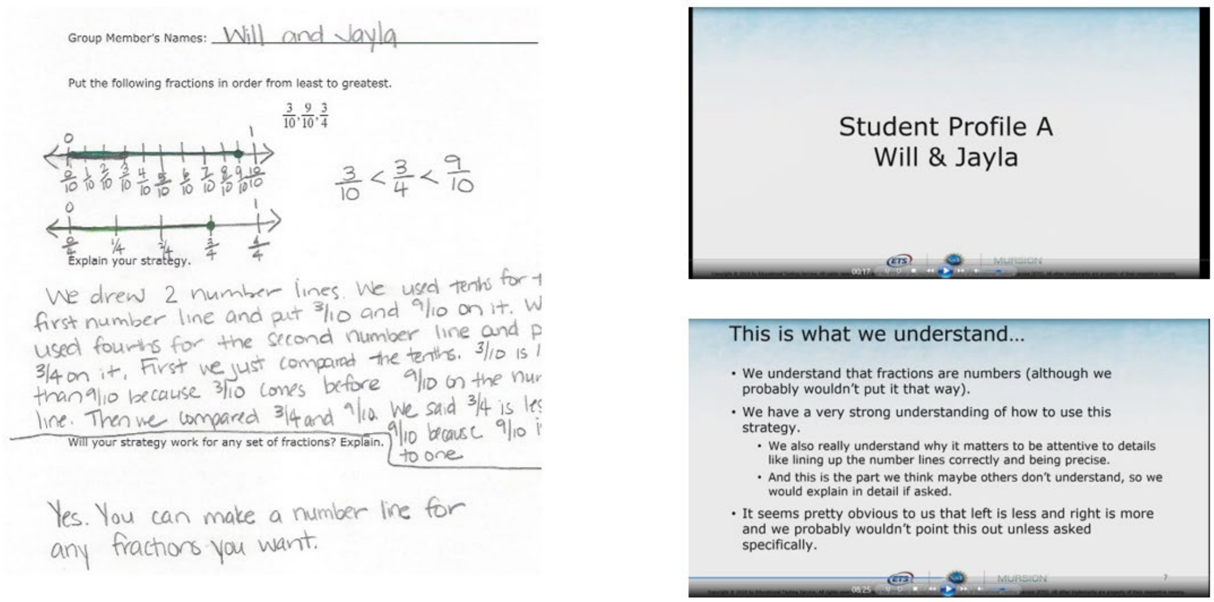
The content of the preservice teacher and interactor components are deeply intertwined. For example, a core part of the preservice teacher–facing materials is the presentation of student work that the student avatars have completed in advance of the simulated discussion (component: Student Responses). Every task includes this component, although the number of student groups varies. For each task, then, this necessitates a parallel component of the interactor training (component: Task-Specific Lessons 1 & 2) in which the interactor learns the student avatars' initial ideas and the work they have done prior to the discussion as well as their dynamic content profiles that dictate how their understandings would change over time in response to the teacher's (or other student avatars') statements or questions.

Table 3. Components of the Interactor Training Materials

Component	Purpose
Non-Task-Specific Training	The non-task-specific training materials cover the discussion construct, direct interactors in how to be responsive to teacher prompts to engage in student-to-student interaction, and include the "testing the waters" guidelines. This component also includes independent study of the warm-up activity materials and culminates with an interactive practice session between the interactor and a trainer.
Task-Specific Lessons 1 & 2	For each task, Lesson 1 is an overview of the task and Lesson 2 is an overview of the student profiles for that task, including independent video-guided study of what each student thinks initially as well as how their thinking may shift over time.
Task-Specific Lesson 3: The Student Profile Check Out	Lesson 3 is a face-to-face session in which the trainer leads the interactor through a standardized set of questions to ensure adequate mastery of the student profiles for the task.
Task-Specific Lesson 4: The Observational Workshop	For Lesson 4, the interactor meets with two trainers, one of whom plays the part of a teacher and enacts four separate practice discussions while the second trainer provides targeted feedback on the interactor's performance. The four teacher profiles are carefully constructed to represent the breadth of discussion approaches the interactor is likely to encounter.
Task-Specific Lesson 5: The Final Check Out	Lesson 5 is also a face-to-face session with a trainer who enacts two more teacher profiles. Recordings of the session are uploaded and scored by the trainer for adequate fidelity to interactor training guidelines.

For example, for the Ordering Fractions task, the written student work explains clearly what Will and Jayla did to solve the problem and why they think their strategy would always work. The accompanying interactor training specifies that their understanding of how to use the strategy should be strong, that they would press on the fine detailed points of the drawing, and what they would emphasize if explaining the approach to others. It would also note which parts seem obvious enough that they would likely not mention them as part of such an explanation (Figure 4).

Figure 4. Linked Components of Materials Include Student Work (for the Preservice Teacher) and Instructional Videos (for the Interactor)



All components were designed, to the greatest extent possible, to be uniform in ways that are adaptation-friendly, allowing for the insertion of new content as needed to create new tasks. We next discuss some of the critical design considerations that informed our design of the task components using specifics from the Ordering Fractions task to illustrate how some of these considerations are taken up and addressed in this performance task.

Design Consideration: Knowing Where to Start

The stand-alone Introduction to the Simulated Classroom as well as the Introduction to the Task and Lesson Overview components of the preservice teacher–facing materials are collectively intended to support the preservice teacher in knowing how to begin the discussion. In early tryouts, we realized that one of the logistical elements of the simulation we needed to manage was launching the preservice teacher straight into the discussion, as each teacher has only 20 minutes of simulation time and needs to use it for the intended interactive work of facilitating a discussion. A preservice teacher who spends time doing something else might well use up the full 20 minutes without engaging in the intended content discussion. For example, a natural starting point for preservice teachers encountering new students is to review prior knowledge, but reviewing what they already know takes time away from addressing the student learning goal in the task during the discussion. The Introduction to the Simulated Classroom, Introduction to the Task, and Lesson Overview components acquaint the preservice teacher with the students' prior knowledge and describe exactly what has come before the discussion so that the preservice teacher has a clear sense of where they are to begin the discussion.

Design Consideration: Understanding the Task Purpose

One area in which we found it necessary to build in substantial support across task components was helping the preservice teachers understand that they should be encouraging students to interact with one another directly. Many novice teachers struggle to engage students in this way. In contrast, a frequent and less productive pattern of engagement is known as the initiate—respond—evaluate (IRE) response pattern (Cazden, 1988) in which the teacher interacts with individual students in turn, intervening at each step. One goal of these performance tasks is to support preservice teachers in learning to avoid this pattern. However, if the preservice teachers interpret the instruction to "facilitate a discussion" as asking them to engage in IRE, they may not realize that they are not attempting to meet the intended goal. Paired with a technology environment in which a preservice teacher may not realize the students can speak to one another directly, there is some risk of misdirection on the preservice teacher's part. That misdirection would have represented a source of measurement error for us as it would be difficult to distinguish performances in which the preservice teacher was unable to elicit student interaction from those in which the preservice teacher did not understand that student interaction was possible.

We sought to counter this challenge in several ways across components of both the preservice teacher–facing and interactor training materials. First, we clarified the discussion goal across all tasks to make it clear that student-to-student interaction was possible and desirable. For example, Figure 5 shows text from the Introduction to the Task component stating, "You can encourage the students to talk to one another, ask one another questions, and respond to one another's ideas." Along with this instruction is a teaching tip bubble that cautions the preservice teacher to allow wait time for students to respond.

Figure 5. Text From the Introduction to the Task Component Supporting Student-to-Student Dialogue

TEACHING TIP:
The student avatars are not computer programmed, so it may take them a little time to think and respond.

You will have up to 20 minutes to lead this discussion in a simulated classroom environment made up of five upper-elementary student avatars. The students will be able to hear and see you, and they will respond in real time just like students in a real classroom. You can encourage the students to talk to one another, ask one another questions, and respond to one another's ideas.

Depending on how the discussion unfolds, you may or may not reach a satisfying conclusion by the end of the session time, and it is fine if you do not. If you do not reach a satisfying conclusion, just wrap up the discussion and indicate that you will pick the discussion up during the next class.

Then, on the interactor side, we built in two deliberate instances of student-to-student dialogue intended to help make sure the preservice teacher is aware that direct student interaction is possible (both of these instances are addressed as part of non-task-specific training as they are common across all eight tasks). First, during the warm-up task, one student jumps in and speaks directly to another student. Second, at some point during the first few minutes of the discussion, the interactor is instructed to engage in what we call "testing the waters," by having one student jump in and engage in a brief back-and-forth dialogue with another. In general, the interactor will not have the students engage in this way without prompting, as the preservice teacher is supposed to be learning how to elicit such interaction. But for testing the waters, the interactor makes an exception. This dialogue serves two purposes: First, it is an additional reinforcement to the preservice teacher that students can speak directly with one another, and second, it gives the interactor valuable information about the preservice teacher's initial stance toward how student centered they would like the discussion to be. If the preservice teacher tries to quiet the students or asks them to raise hands, these are signs that the preservice teacher may be discouraging direct student-to-student interaction. However, if the preservice teacher encourages or praises the students or tries to build on the interaction, these are signs that the preservice teacher may be encouraging it.

Design Consideration: Support in Unpacking Student Thinking

Each task is designed on the premise that students have already worked on a given problem in advance of being called together to discuss their work. The students' written work is provided ahead of time (task component: Student Responses) so that the preservice teacher can review and plan the discussion based on it. In addition, we provide information to the preservice teacher to help them make sense of the written student work (task component: Making Sense of the Student Work). This text specifies, for example, whether the answer the students have given is correct, partially correct, or incorrect and what they might have been thinking about and calls attention to important things the preservice teacher might notice or pay attention to in planning the discussion. For example, for Will and Jayla's work discussed previously, this text states that their answer is correct, the strategy is also correct, and their final claim is ambiguous (Figure 6). Further, it directs the teacher to notice a number of points that make it clear Will and Jayla have a solid grasp of how to use number lines, including the relative sophistication of stacking the number lines as they have done. It also points out that while their claim that the method would always work is true in theory, this method would be difficult to apply practically in two types of situations. Noticing this last point creates an opportunity for the preservice teacher to support student engagement in argumentation, as it identifies their claim as one that is open to challenge and about which the other students might well disagree.

Figure 6. Making Sense of the Student Work Component for Will and Jayla

Making Sense of Will and Jayla's Work

Are their answers correct?

- They are correct that $\frac{3}{10} < \frac{3}{4} < \frac{9}{10}$.
- Their strategy is also correct.
- Their claim that the strategy would always work is ambiguous.

Things to notice about Will and Jayla's strategy for ordering fractions:

- This strategy works well for these three fractions. However, the success of the strategy depends on how accurately you can place the fractions on the number line. This means the quality of the drawing has to be good in order for the method to work. In this case, the drawing looks quite accurate, the two number lines are lined up correctly, and the fractions are spaced out from one another sufficiently to be able to tell how to order them.
- There are a number of things that make it clear they understand this approach well and have done a thorough job in their work, including:
  - Careful attention to equal partitions.
  - Lining up 0 and 1 on the two number lines.
  - "Stacking" the two number lines one above the other to make it easy to see the comparison.
  - Putting $\frac{3}{10}$ and $\frac{9}{10}$ on the same number line.

Things to notice about Will and Jayla's explanation:

- The explanation of the strategy is fairly complete and likely to be followed without difficulty by other students.

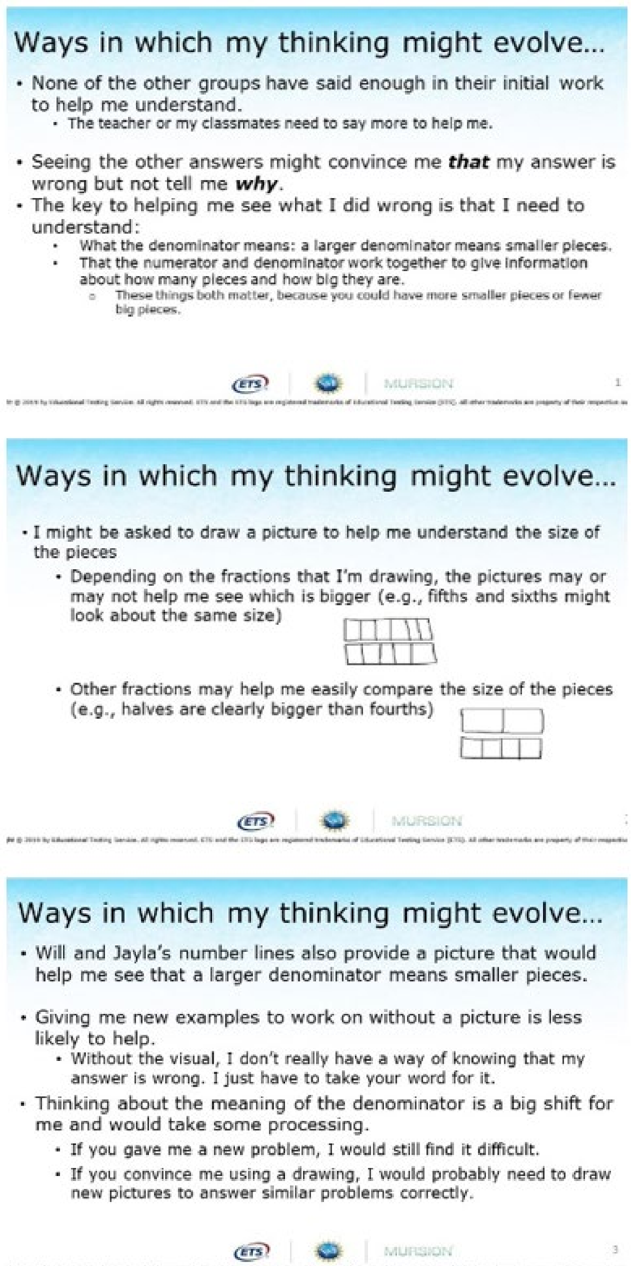
Things to notice about Will and Jayla's claim about the strategy always working:

- It is true *in theory* that you could make a number line for any fraction, but for some fractions it would be difficult to draw it correctly (for example, fractions with large denominators). For other sets of fractions it might be hard to draw accurately enough to compare them (for example, $\frac{7}{10}$ and $\frac{3}{4}$ would be hard to compare on the number lines they drew). So the strategy is impractical in many cases.

Design Consideration: Static and Dynamic Student Profiles

As mentioned previously, interactor training includes both static profiles for students' personalities and initial content ideas as well as dynamic profiles reflecting their likely patterns of change. One characteristic of these tasks is that the students will contribute most of the key ideas if the preservice teacher is facilitating the discussion in a productive way. This means that interactors need training in both when to introduce those ideas and how the individual student avatars should respond to those ideas or sets of ideas, whether presented by the preservice teacher or by other students in response to the preservice teacher's prompting.

Figure 7. Slides From the Interactor Training: Unlocking Mina's Thinking



In the Ordering Fractions task, for example, one student, Mina, proposes an incorrect strategy. The interactor training (Figure 7) notes specific ways in which her thinking would (and would not) shift, including noting that just seeing the other students' work would be insufficient for Mina to change her thinking, and seeing that her answer is wrong would convince her that she did something incorrect but would not help her understand why. The interactor training materials specify two key ideas that would need to be addressed during the discussion to shift Mina's understanding: First, that in the context of a given numerator, a larger denominator means smaller pieces and vice versa, and second, that information about both the size and the number of pieces is needed to determine the relative relationship of two fractions. Those ideas could come from classmates, the teacher, or a combination. It also clarifies what types of visual representations would be more or less helpful and outlines how Mina would respond to examples in the absence of a visual, or to new problems, each of which is a likely idea for the preservice teacher to raise or prompt during the discussion.

Conclusion

The preservice teacher–facing materials for the Ordering Fractions task can be found in the appendix. Our goal in this project was to create a set of simulation-based performance tasks that can be used to support preservice teachers in learning how to facilitate argumentation-focused discussions in two content areas: mathematics and science. In that project work, we video recorded each preservice teacher's discussion session for each task and provided detailed written feedback as well as access to the video to both the preservice teacher and the course teacher educator. We hypothesized that that preservice teacher would be supported on multiple levels. First, there is an aspect of experiential learning, as the preservice teacher sees the student avatars engage in response to their prompts during the simulation. Second, the preservice teacher learns from the written feedback. Although we provided feedback to the preservice teachers, that feedback could also come from a teacher educator or coach, or the preservice teacher could be guided in self-reflection. Third, the performance tasks provide a type of formative assessment information to the teacher educator who can see, in looking across the videos or the feedback, patterns in the class or the individual performance that allow the teacher educator to adjust instruction within the methods course.

Our design process was deliberately systematic and was intended to support productive adaptation of the task materials that resulted. Although our work took place in the context of preservice teacher learning and for use with the Mursion simulated classroom environment, the tasks could easily be used for professional development and adapted for use in other simulation environments using other technologies or nontechnological approaches. For example, a teacher educator or coach might use the materials for the basis of live role playing and adapt the interactor training materials to help preservice teachers play the role of students. The full set of project materials, including interactor training materials and guidelines for scoring the discussions, is archived in an online repository (https://data.qdr.syr.edu/dataverse/go-discuss) and is publicly available for use and adaptation.

References

Ball, D. L. (1993). Halves, pieces, and twoths: Constructing and using representational contexts in teaching fractions. In T. P. Carpenter, E. Fennema, & T. A. Romberg (Eds.), *Rational numbers: An integration of research* (pp. 157–195). Lawrence Erlbaum Associates.

Ball, D. L., & Forzani, F. M. (2011). Building a common core for learning to teach: And connecting professional learning to practice. *American Educator, 35*(2), 17–38.

Barkai, R., Tsamir, P., Tirosh, D., & Dreyfus, T. (2002). Proving or refuting arithmetic claims: The case of elementary school teachers. In A. D. Cockburn & E. Nardi (Eds.), *Proceedings of the Twenty-Sixth Annual Meeting of the International Group for the Psychology of Mathematics Education* (Vol. 2, pp. 57–64). University of East Anglia, School of Education and Professional Development.

Cazden, C. B. (1988). *Classroom discourse: The language of teaching and learning.* Heinemann.

Design-Based Research Collective. (2003). Design-based research: An emerging paradigm for educational inquiry. *Educational Researcher, 32*(1), 5–8. https://doi.org/10.3102/0013189X032001005

Howell, H., & Mikeska, J. N. (2021). Approximations of practice as a framework for understanding authenticity in simulations of teaching. *Journal of Research on Technology in Education, 53*(1), 8–20. https://doi.org/10.1080/15391523.2020.1809033

Kazemi, E., & Stipek, D. (2009). Promoting conceptual thinking in four upper-elementary mathematics classrooms. *Journal of Education, 189*(1–2), 123–137. https://doi.org/10.1177/0022057409189001-209

Lamon, S. B. (2012). *Teaching fractions and ratios for understanding: Essential content knowledge and instructional strategies for teachers*. Routledge.

Martin-Raugh, M., Reese, C. M., Howell, H., Tannenbaum, R. J., Steinberg, J. H., & Xu, J. (2016). *Investigating the relevance and importance of mathematical content knowledge areas for beginning elementary school teachers* (Research Memorandum No. RM-16-10). ETS.

Mikeska, J. N., Howell, H., & Straub, C. (2019). Using performance tasks within simulated environments to assess teachers' ability to engage in coordinated, accumulated, and dynamic (CAD) competencies. *International Journal of Testing*, *19*(2), 128–147. https://doi.org/10.1080/15305058.2018.1551223

Mislevy, R. J., Steinberg, L. S., & Almond, R. G. (2002). On the structure of educational assessments. *Measurement: Interdisciplinary Research and Perspectives, 1*(1), 3–62. https://doi.org/10.1207/S15366359MEA0101_02

National Governors Association Center for Best Practices & Council of Chief State School Officers. (2010). *Common Core State Standards for Mathematics*.

National Research Council. (2013). *Next Generation Science Standards: For states, by states*. The National Academies Press.

Newton, K. J. (2008). An extensive analysis of preservice elementary teachers' knowledge of fractions. *American Educational Research Journal, 45*(4), 1080–1110. https://doi.org/10.3102/0002831208320851

Reid, D., & Zack, V. (2009). Aspects of teaching proving in upper elementary school. In D. A. Stylianou, M. L. Blanton, & E. J. Kruth (Eds.), *Teaching and learning proof across the grades: A K–16 perspective* (pp. 133–146). Routledge.

Russell, S. J. , Schifter, D., Bastable, T., & Kasman, R. (2017). *But why does it work?: Mathematical argument in the elementary classroom.* Heinemann.

Stylianides, A. J., Bieda, K. N., & Morselli, F. (2016). Proof and argumentation in mathematics education research. In A. Gutiérrez, G. C. Leder, & P. Boero (Eds.), *The second handbook of research on the psychology of mathematics education* (pp. 315–351). Sense Publishers. https://doi.org/10.1007/978-94-6300-561-6_9

Walshaw, M., & Anthony, G. (2008). The teacher's role in classroom discourse: A review of recent research into mathematics classrooms. *Review of Educational Research, 78*(3), 516–551. https://doi.org/10.3102/0034654308320292

Appendix: The Ordering Fractions Preservice Teacher–Facing Task Materials

ETS Research Study on Facilitating Student Discussions
The Ordering Fractions Discussion Task

Credit: Image courtesy of Mursion

Table of Contents

Note: The materials provided in the following sections are designed to help you plan for your discussion and should help you understand what you are supposed to do. You will also find teaching tips embedded throughout the document. An additional document, "An Introduction to the Simulated Classroom and Student Avatars," is also available for your use.

TEACHING TIP:
The teaching tips are designed to enhance your understanding of the task and your performance. You are **not** required to use them; instead they are here for you to use however you wish.

Introduction to the Ordering Fractions Discussion Task

What is the student learning goal for this discussion?

Student Learning Goal

Students will evaluate, justify, compare, and contrast strategies for ordering fractions with different numerators and different denominators.

What will you do?

You will lead a discussion during which you should focus on the following.

- The strategies the students used to order the fractions
- Why their strategies are or are not mathematically valid
- Whether the strategies would work in general

Your focus should be on engaging the students in discussion with one another and in the practice of argumentation. During the discussion, be sure to have students focus on evaluating and justifying their strategies and not just on getting the right answer.

TEACHING TIP: Part of what makes this a great problem for students to work on is that there is no single best strategy.

TEACHING TIP: The student avatars are not computer programmed, so it may take them a little time to think and respond.

You will have up to 20 minutes to lead this discussion in a simulated classroom environment made up of five upper-elementary student avatars. The students will be able to hear and see you, and they will respond in real time just like students in a real classroom. You can encourage the students to talk to one another, ask one another questions, and respond to one another's ideas.

Depending on how the discussion unfolds, you may or may not reach a satisfying conclusion by the end of the session time, and it is fine if you do not. If you do not reach a satisfying conclusion, just wrap up the discussion and indicate that you will pick the discussion up during the next class.

Lesson Overview

TEACHING TIP: Everything you do in planning for and leading this discussion should help the students make progress toward the student learning goal.

Student Learning Goal: Evaluate, justify, compare, and contrast strategies for ordering fractions with different numerators and different denominators.

Background: The students are in fifth grade. They know what the words "numerator" and "denominator" refer to, and how to write fractions in standard notation (e.g., one half is $\frac{1}{2}$).

Students have experience, but may not be proficient, with the following.

- Fractions with denominators 2, 3, 4, 5, 6, 8, 10, 12, and 100
- Representing fractions using number lines and fraction bars, although they may not draw the number lines perfectly (e.g., with equal-sized wholes or equal-sized increments)
- Reasoning about the size of fractions using benchmarks like $\frac{1}{2}$
- Reasoning about the size of fractions by considering the denominator (the size of the pieces) and the numerator
- Working with equivalent fractions

Note: Not every student has the same level of understanding or ability with the content ideas and practices noted above, but these are the learning opportunities that all students in this classroom have previously experienced.

Prior to starting the discussion:

- Students were given the assignment shown here. Students worked in small groups. Will and Jayla worked together, Emily and Carlos worked together, and Mina worked alone.
- The students wrote their work on the iPad shared workspace in preparation for sharing with the class. (Their written work is shown in the following sections, and their work on the iPad will be available to you to display and write on during your discussion with the students.)

Group Member's Names: ____________________

Put the following fractions in order from least to greatest.

$$\frac{3}{10}, \frac{9}{10}, \frac{3}{4}$$

Explain your strategy.

Will your strategy work for any set of fractions? Explain.

TEACHING TIP:
The correct order is $\frac{3}{10} < \frac{3}{4} < \frac{9}{10}$, but remember that the students' strategies are the main focus!

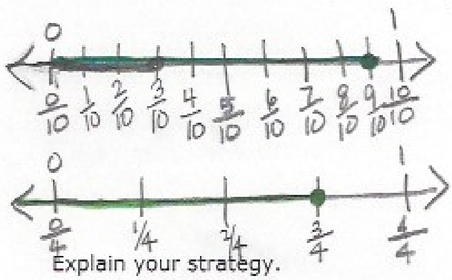
TEACHING TIP:
Try to focus the discussion on the students' strategies, not on other strategies that can be used to compare.

Student Responses: Will and Jayla's Work

Group Member's Names: Will and Jayla

Put the following fractions in order from least to greatest.

$\frac{3}{10}, \frac{9}{10}, \frac{3}{4}$



$\frac{3}{10} < \frac{3}{4} < \frac{9}{10}$

Explain your strategy.

We drew 2 number lines. We used tenths for the first number line and put 3/10 and 9/10 on it. We used fourths for the second number line and put 3/4 on it. First we just compared the tenths. 3/10 is less than 9/10 because 3/10 comes before 9/10 on the number line. Then we compared 3/4 and 9/10. We said 3/4 is less than 9/10 because 9/10 is closer to one.

Will your strategy work for any set of fractions? Explain.

Yes. You can make a number line for any fractions you want.

Making Sense of Will and Jayla's Work

Are their answers correct?

- They are correct that $\frac{3}{10} < \frac{3}{4} < \frac{9}{10}$.
- Their strategy is also correct.
- Their claim that the strategy would always work is ambiguous.

Things to notice about Will and Jayla's strategy for ordering fractions:

- This strategy works well for these three fractions. However, the success of the strategy depends on how accurately you can place the fractions on the number line. This means the quality of the drawing has to be good in order for the method to work. In this case, the drawing looks quite accurate, the two number lines are lined up correctly, and the fractions are spaced out from one another sufficiently to be able to tell how to order them.
- There are a number of things that make it clear they understand this approach well and have done a thorough job in their work, including
  - Careful attention to equal partitions.
  - Lining up 0 and 1 on the two number lines.
  - "Stacking" the two number lines one above the other to make it easy to see the comparison.
  - Putting $\frac{3}{10}$ and $\frac{9}{10}$ on the same number line.

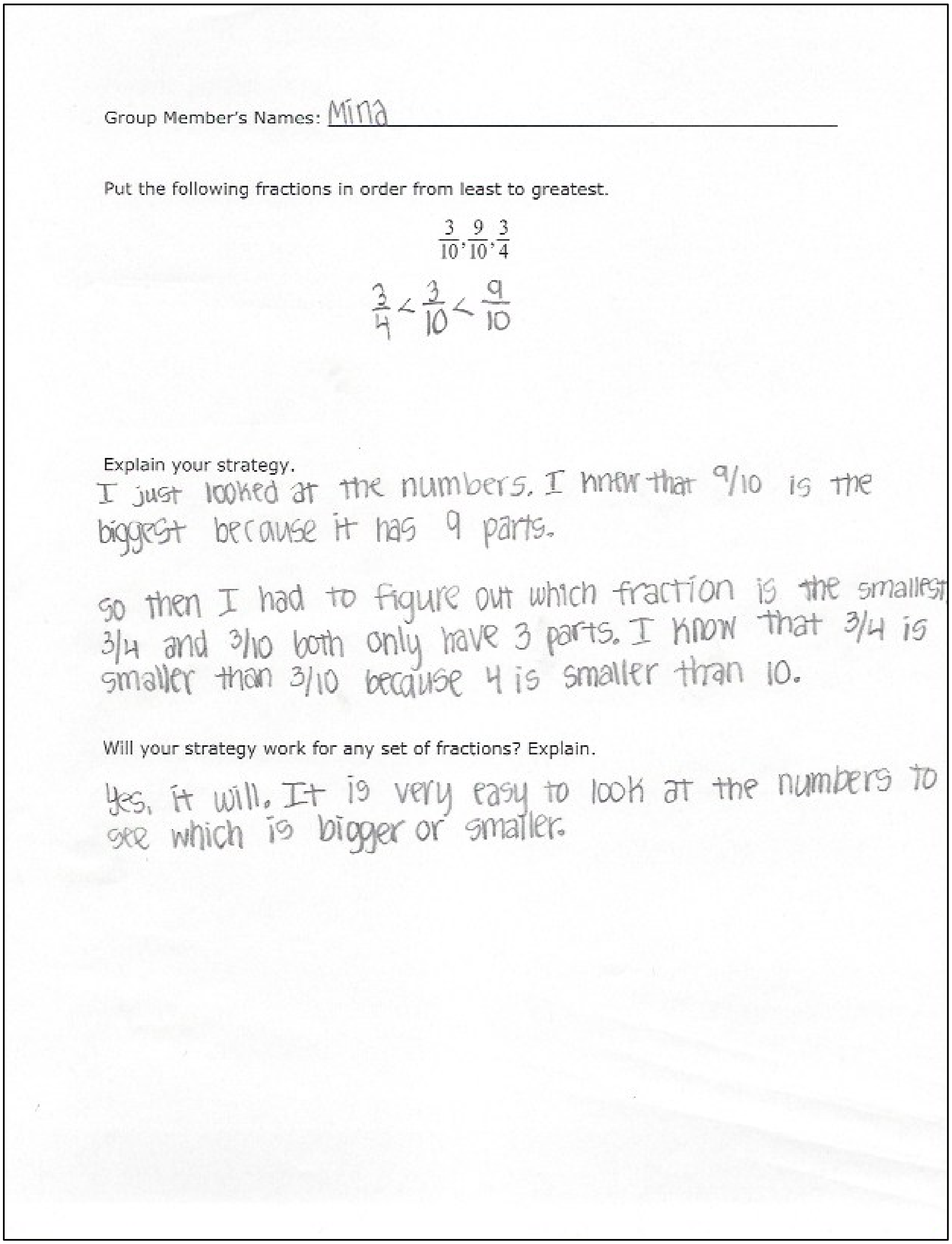
Things to notice about Will and Jayla's explanation:

- The explanation of the strategy is fairly complete and likely to be followed without difficulty by other students.

Things to notice about Will and Jayla's claim about the strategy always working:

- It is true *in theory* that you could make a number line for any fraction, but for some fractions it would be difficult to draw it correctly (for example, fractions with large denominators). For other sets of fractions, it might be hard to draw accurately enough to compare them (for example, $\frac{7}{10}$ and $\frac{3}{4}$ would be hard to compare on the number lines they drew). So the strategy is impractical in many cases.

Student Responses: Mina's Work


Group Member's Names: Mina

Put the following fractions in order from least to greatest.

$\frac{3}{10}, \frac{9}{10}, \frac{3}{4}$

$\frac{3}{4} < \frac{3}{10} < \frac{9}{10}$

Explain your strategy.

I just looked at the numbers. I knew that 9/10 is the biggest because it has 9 parts.

so then I had to figure out which fraction is the smallest 3/4 and 3/10 both only have 3 parts. I know that 3/4 is smaller than 3/10 because 4 is smaller than 10.

Will your strategy work for any set of fractions? Explain.

yes, it will. It is very easy to look at the numbers to see which is bigger or smaller.

Making Sense of Mina's Work

Are her answers correct?

- Mina is partially correct that $\frac{3}{4} < \frac{3}{10} < \frac{9}{10}$ because $\frac{9}{10}$ is the greatest fraction.

  However, $\frac{3}{4}$ is greater than $\frac{3}{10}$.
- Her strategy is incorrect, although coincidentally it leads to a partially correct answer.
- Her claim that the strategy would always work is also incorrect.

Things to notice about Mina's strategy for ordering fractions:

- Although Mina's strategy is incorrect, there are some important ideas to consider. There are correct ways to compare fractions by comparing numerators and denominators separately, but they only work some of the time, and it requires understanding what the numbers represent.
  - If both denominators are the same, then the sizes of the pieces are the same; therefore, comparing numerators (number of equal-sized pieces) directly is correct.
  - If both numerators are the same, then you have the same number of pieces. You can, therefore, compare the denominators, but you have to keep in mind that you are thinking about the size of the pieces, and a larger denominator means smaller pieces.
  - In cases where neither the numerators nor the denominators are the same, this strategy is considerably more complicated.

Things to notice about Mina's explanation:

- Mina's explanation is easy to follow but does not provide a lot of detail as to why she approached the problem this way or how she drew particular conclusions.
- Although $\frac{9}{10}$ is the greatest fraction, Mina's reasoning for why is incomplete; she cannot draw that conclusion on the basis of comparing numerators alone.

Things to notice about Mina's claim about the strategy always working:

- While Mina's claim that her method would always work is not correct, she is correct in observing that comparing whole numbers is easy. This means that in the special cases described above where this strategy does work, it's an efficient strategy to choose.

Student Responses: Emily and Carlos' Work

Group Member's Names: Emily and Carlos

Put the following fractions in order from least to greatest.

$$\frac{3}{10}, \frac{9}{10}, \frac{3}{4}$$

$$\frac{3}{10} < \frac{3}{4} < \frac{9}{10}$$

Explain your strategy.

First we compared the fractions to 1/2. 3/10 is less than $\frac{1}{2}$ and $\frac{9}{10}$ is more than $\frac{1}{2}$. $\frac{3}{4}$ is more than $\frac{1}{2}$ also.

This makes $\frac{3}{10}$ the smallest because it is the only fracti less than $\frac{1}{2}$.

$\frac{9}{10}$ is way bigger than $\frac{3}{4}$ because both are only 1 part away from 1. Tenths are smaller than fourths so that means $\frac{9}{10}$ is missing a smaller piece than $\frac{3}{4}$.

Will your strategy work for any set of fractions? Explain.

No. You can always decide if it is more or less than 1/2 but some fractions are still hard to compare after that.

Making Sense of Emily and Carlos' Work

Are their answers correct?

- They are correct that $\frac{3}{10} < \frac{3}{4} < \frac{9}{10}$.
- Their strategy is also correct.
- Their claim that the strategy would not always work is correct.

Things to notice about Carlos and Emily's strategy for ordering fractions:

- Their strategy is actually a combination of three strategies:
  - Compare each fraction to $\frac{1}{2}$ to determine whether the fraction is greater than or less than $\frac{1}{2}$.
  - For the two fractions that are greater than $\frac{1}{2}$, compare the size of the missing pieces, since each is missing only one piece.
  - Note that a larger denominator means the smaller piece, so the fraction missing the larger denominator piece is missing less. Therefore, it is greater.
- Each strategy is applied correctly and is reasonable for the given problem. Also, the three strategies are coordinated correctly with one another and with some degree of sophistication.

Things to notice about Carlos and Emily's explanation:

- Although the explanation is reasonable, it is incomplete on some points and might be difficult for other students to follow easily.

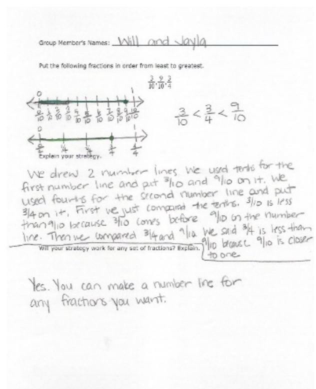
Things to notice about Carlos and Emily's claim about the strategy always working:

- Their claim that the strategy would not always work is correct, and the justification is reasonable but not thorough.
  - It's a little ambiguous what the first part of the justification means; it's true that you can always compare fractions to $\frac{1}{2}$, but this is helpful only if some of the fractions are greater than $\frac{1}{2}$ and some are less than $\frac{1}{2}$ (i.e., if all three were greater than $\frac{1}{2}$, this step would not tell you anything).
  - Although it's true that some fractions are still hard to compare after that, it's not clear exactly what they mean by this or what types of fractions they have in mind.

Shared Workspace Pages

The following are images of the shared workspace pages that will be available on the tablet. You and the students will be able to access and interact with these pages during the discussion. The tools on the toolbar can be used to draw or write on the pages. Blank pages are also available for you to use during the discussion.

Will and Jayla's Work



Group Member's Names: Will and Jayla

Put the following fractions in order from least to greatest.

$\frac{3}{10}, \frac{9}{10}, \frac{3}{4}$

$\frac{3}{10} < \frac{3}{4} < \frac{9}{10}$

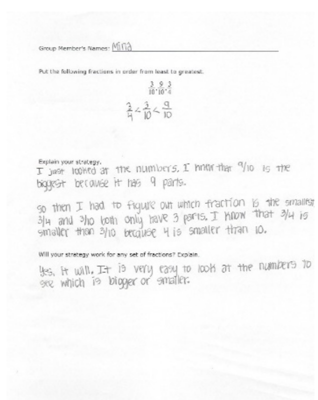
Explain your strategy.

We drew 2 number lines. We used tenths for the first number line and put 3/10 and 9/10 on it. We used fourths for the second number line and put 3/4 on it. First we just compared the tenths. 3/10 is less than 9/10 because 3/10 comes before 9/10 on the number line. Then we compared 3/4 and 9/10. We said 3/4 is less than 9/10 because 9/10 is closer to one.

Will your strategy work for any set of fractions? Explain.

Yes. You can make a number line for any fractions you want.

Mina's Work



Group Member's Names: Mina

Put the following fractions in order from least to greatest.

$\frac{3}{10}, \frac{9}{10}, \frac{3}{4}$

$\frac{3}{4} < \frac{3}{10} < \frac{9}{10}$

Explain your strategy.

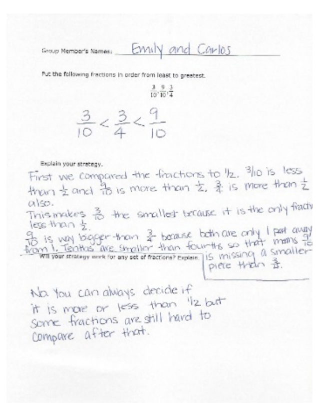
I just looked at the numbers. I know that 9/10 is the biggest because it has 9 parts.

so then I had to figure out which fraction is the smallest. 3/4 and 3/10 both only have 3 parts. I know that 3/4 is smaller than 3/10 because 4 is smaller than 10.

Will your strategy work for any set of fractions? Explain.

Yes, it will. It is very easy to look at the numbers to see which is bigger or smaller.

Carlos and Emily's Work



Group Member's Names: Emily and Carlos

Put the following fractions in order from least to greatest.

$\frac{3}{10}, \frac{9}{10}, \frac{3}{4}$

$\frac{3}{10} < \frac{3}{4} < \frac{9}{10}$

Explain your strategy.

First we compared the fractions to 1/2. 3/10 is less than 1/2 and 9/10 is more than 1/2. 3/4 is more than 1/2 also.

This makes 3/10 the smallest because it is the only fraction less than 1/2.

9/10 is way bigger than 3/4 because both are only 1 part away from 1. Tenths are smaller than fourths so that means 9/10 is missing a smaller piece than 3/4.

Will your strategy work for any set of fractions? Explain.

No. You can always decide if it is more or less than 1/2 but some fractions are still hard to compare after that.

Features of High-Quality Discussions Focused on Argumentation

The discussion task you have been asked to complete is complex, and there are multiple approaches that you might take. The following list is a series of reflection questions for you to consider as you plan to lead a productive **discussion focused on engaging students in the practice of argumentation**. These features identify the main characteristics of high-quality discussions focused on argumentation. You might expect a helpful observer, such as a coach, peer, or instructor, to provide feedback on these features when observing your teaching in order to help you reflect on and learn from the experience.

1. **Attending to Students' Ideas:** Did I make sure every student's voice was heard and that all students' ideas were valued?
    - Did I give every student an opportunity to participate in meaningful ways?
    - Did I make sure to include all ideas that students shared in their previous work?
2. **Facilitating a Coherent and Connected Discussion:** Did the discussion make sense and feel organized and purposeful to the students?
    - Did I help the students make connections among ideas that build toward a shared understanding?
    - Did I help the students make sense of the discussion so that they could summarize the main takeaways and know what was learned?
3. **Encouraging Student-to-Student Interactions:** Did I succeed in getting students to engage in discussion with one another?
    - Did I encourage students to speak to one another directly?
    - Did I provide opportunities for students to pose questions to one another or comment on and critique one another's ideas?
4. **Developing Students' Conceptual Understanding:** Did I support students in developing a correct content understanding during the discussion?
    - Did I represent mathematics concepts correctly?
    - Did I give students opportunities to evaluate the correctness of content ideas so that they could learn how to be part of the process of critiquing those ideas?
    - Did I consider any mathematics content errors students had during the discussion and support students in working together to address those areas of confusion?
5. **Engaging Students in Argumentation:** Did the discussion allow students to engage in argumentation?
    - Did I focus the discussion on ideas that were worth debating?
    - Did I provide opportunities for the students to make claims or conjectures, support them with reasoning or evidence, and consider and critique their own and others' ideas?

TEACHING TIP:
Try to focus the discussion on the students' strategies, not other strategies that can be used to compare fractions.

Video Examples of High-Quality Discussions Focused on Argumentation

Learning how to facilitate discussions focused on argumentation can be challenging. Observing examples of students and teachers engaged in these types of discussions can be helpful. The following video links will allow you to see what it looks like and sounds like when elementary and middle school students engage in productive argumentation in mathematics classrooms. We have also provided you with some questions to think about as you view these video examples and prepare to lead a productive **discussion focused on engaging students in the practice of argumentation**.

Focus	Things to notice	Resources (videos and vignettes)
Promoting student-to-student interaction	• How did the students engage in discussion with one another? • How did the teacher in each video promote student interaction? • What is the role of the teacher in each video and how are they different from one another?	Select the video titled "Strategy: Promoting Student Interaction In Science Seminars." Select the video "Joey's Run Part 1."
Supporting students' ownership of the ideas	• How does the teacher's focus on accurately capturing the students' meaning without changing it support their ownership of the ideas? • What does the teacher do to support a focus on students convincing one another?	Read the transcript of "Grade 4: Finding Equivalent Fractions."
Promoting students' evaluation and critique of competing claims	• How does the teacher use a focus on consensus to move the discussion forward? • How do the teaching moves focus on supporting students' critique?	Review the pdf and video of "Grade 3/4: Crazy Cakes."

Note. Resource examples are drawn from the Argumentation Toolkit website and from Illustrative Mathematics.

Notes

[1] The development of the simulated environment also included feedback from multiple stakeholders, including our advisory board, and a compilation of reviews and iterative refinements to the students' physical appearance as well as their voicing, background, and personality profiles. Although this development process happened concurrently, it is not described in this report.