Achieve

SCIENCE TASK ANNOTATION

ANNOTATION KEY

EQUITY Supporting a wide range of diverse students.

SCENARIOS Information provided to elicit performances.

SEPs Opportunities to demonstrate science and engineering practices.

DCIs Opportunities to demonstrate understanding of disciplinary core ideas.

CCCs Opportunities to demonstrate understanding of crosscutting concepts.

SENSE-MAKING Opportunities for reasoning about phenomena and problems.

ASSESSMENT PURPOSE Highlights how the task features connect to intended assessment use.

ACTIVITY 3.2: DOES 5 + 5 ALWAYS EQUAL 10?

ACTIVITY 3.2-TEACHER PREPARATION

SUMMARY

Students will mix different combinations of water and ethanol, and compare predicted and observed volumes. Students will then explore a simulation that allows them to compare the particle and continuous model of matter. Based on their observations, students will evaluate whether the continuous or particle model best explains why the volume of the water and ethanol mixture is less than the sum of the volumes of the two separate liquids.

In the previous activity, students shared their initial ideas about the nature of matter. The purpose of this activity is for students to gather evidence to begin to make arguments about whether the particle or continuous model of matter is most useful for explaining phenomena. In upcoming activities, students will continue to collect evidence to support one model over the other. Once students have evidence supporting the particle model, they will develop an atomic model that can be used to explain their earlier observations of electrostatic phenomena.

LEARNING GOAL

Students will evaluate whether the continuous or particle model of matter best accounts for their observations of a mixture.

- When water and ethanol are mixed, the total volume is less than the sum of the volumes of the original liquids. The particle model can explain this loss in volume because in a mixture, the different particle shapes may more efficiently pack together.

Each investigation in this unit begins with a description of the PE that the activities build toward, the specific elements from NGSS that students will use, and a description of how the investigation makes use of each of those elements.

This introductory section provides an invaluable reference to help teachers recognize where they can expect to see evidence of each element and gives them a clear goal for what they are building toward.

Each activity in the investigation, also begins by laying out very explicitly the learning goal and each dimension that students are using. By stating how students are expected to be able to use the content to explain the phenomenon from the outset and common incorrect models that students use (below), teachers have a clear learning goal and level of sophistication that they can listen for in students' responses.

CCCs DCIs SEPs

CONNECTION TO ASSESSMENT PURPOSE

ACTIVITY 3.2: DOES 5 + 5 ALWAYS EQUAL 10? (CONTINUED)

ACTIVITY 3.2-TEACHER PREPARATION

Disciplinary core idea	Crosscutting concept	Scientific and engineering practice
Structure and properties of matter: Matter of any type can be subdivided into particles that are too small to see, but even then the matter still exists and can be detected by other means. (NGSS Lead States, p. 43)	***Patterns:*** Students observe patterns in systems at different scales andcite patterns as empirical evidence for causality in supporting their explanations of phenomena. (NGSS Appendix G, p.82)	***Obtaining, evaluating, and communicating ideas:*** • Evaluate the merits and limitations of two different models of the same proposed tool, process, mechanism or system in order to select or revise a model that best fits the evidence or design criteria. • Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system. (NGSS Appendix F, p. 65)

POINT FOR CONSIDERATION

Students often have a difficult time understanding the particle nature of matter. As students learn about atoms, they often think of the particles as floating in the material rather than making up the material (i.e., they do not think there is some empty space between the particles even in solids and liquids).

PREPARATION

Class Time: 60 min.

Materials (for each group)

- two 10 mL graduated cylinders (They need to be fairly skinny with at least 1 mL graduations.)
- water
- ethanol (10 mL) in container with lid and droppers
- two stoppers (Each stopper should be the correct size to plug the opening of the graduated cylinder.)

Activity Setup

- Construct a materials kit for each group.
- Print out lab instructions for mixing solutions experiment.

Materials (for demo)

- Two large graduated cylinders (at least 50 mL)
- Enough sand to fill one of the cylinders half way.
- Enough marbles (or other round objects like marbles) to fill one of the cylinders half-way.

SAFETY ISSUES

Ethanol gives off fumes that may be harmful if inhaled. It is also flammable. Make sure students are aware of this and tell them to cover the containers of ethanol with lids when not in use.

HOMEWORK

Worksheet for Activity 3.2: Models of Water and Ethanol (teacher key found here)

ACTIVITY 3.2: DOES 5 + 5 ALWAYS EQUAL 10? (CONTINUED)

ACTIVITY 3.2-TEACHER PREPARATION

BASIC OUTLINE OF ACTIVITY

Use this space to make notes to prepare for your lesson

1. Introduction

   a. Eliciting students' ideas

   b. Sharing students' initial ideas

2. Mixing liquids activity

   a. Investigation

   b. Discussion of results

   c. Models to explain class results

   d. Revisit Driving Question

3. Computer Simulation— Mixing liquids

   a. Discussion of best explanatory model

   b. Revising models

   c. Return to Driving Question

4. Concluding the Lesson

ACTIVITY 3.2: DOES 5 + 5 ALWAYS EQUAL 10? (CONTINUED)

ACTIVITY 3.2-INTRODUCTION

ACTIVITY 3.2 (STUDENT MATERIALS): DOES 5 + 5 ALWAYS EQUAL 10?

Introducing the Lesson

Ask students to recall the differences between the continuous and particle models of matter. Remind them that in science, when there are different ideas or models, evidence needs to be used to make a decision about which model best explains or accounts for observations. In this activity, students will test the continuous and particle models by determining which one can best explain what happens when water and ethanol are mixed.

ACTIVITY 3.2: DOES 5 + 5 ALWAYS EQUAL 10? (CONTINUED)

ACTIVITY 3.2

PAGE TITLE:

INITIAL IDEAS

1. [drawing prompt] In the boxes below, draw models to show what you think water, ethanol, and the mixture of the two would look like if you could zoom in and "see" their structure and composition.

[text prompt] Describe how your model represents the various substances.

Water
Ethanol
Mixture

Student responses: This question is intended to elicit students' initial ideas. They could use either a particle or continuous model as a basis for their speculation about liquids.

- Students often drive squiggly or wavy lines to represent the liquids
- Students may be familiar with a common symbol for water molecules and may draw that or a variation on that

This task uses models very effectively to serve several purposes. Here, the models can be used to provide the teacher with a clear indication of where students are with the ideas they will be working with — where they are with representing the molecules that make up substances and mixtures. It also provides an opportunity for students to track their increasing sophistication with the ideas. Students can see evidence of their own progress by seeing how their models/drawings change over time. This is a nice example of how representing thinking with models can be useful in the classroom, and can surface evidence of both how students are thinking about science ideas as well as how their understanding of modeling is developing.

DCIs SEPs EQUITY

CONNECTION TO ASSESSMENT PURPOSE

ACTIVITY 3.2: DOES 5 + 5 ALWAYS EQUAL 10? (CONTINUED)

ACTIVITY 3.2

2. In drawing your models, did you use the continuous model of matter or the particle model of matter?

A. Continuous model of matter

B. Particle model of matter

Student responses:

A. Continuous model of matter

- Why does your model represent a continuous model?

B. Particle model of matter

- Why does your model represent a particle model?

Discussion

You may want to have a whole-class discussion of students' ideas and representations. Use the portal report to show student work.

Possible questions:

- What are common patterns?
- Who would like to present their model?
- Which of these seem to represent the particle model and which the continuous model?

ACTIVITY 3.2: DOES 5 + 5 ALWAYS EQUAL 10? (CONTINUED)

ACTIVITY 3.2

PAGE TITLE:

MIXING LIQUIDS

In this activity, you will make observations of the behavior of matter. Later, you will evaluate the continuous and particle models of matter to see if one of the models better explains your observations. This will give you some evidence that you can use to evaluate the two models of matter.

After completing the experiment described in the handout linked below, return to this activity to answer the following questions.

Experiment Instructions: Mixing Liquids

Note: When the same liquids are mixed together (water with water, ethanol with ethanol), the volumes are additive. However, when 50 mL of water and 50 mL of ethanol are mixed, the resulting volume is about 95 mL.

3. How does the observed volume of the water/water mixture compare with the total volume you calculated?

A. The mixture had a greater volume than expected (higher than my calculation).

B. The mixture had a lower volume than expected (lower than my calculation).

C. The volume of the mixture was what I expected (equal to my calculation).

Student responses: The actual volume may be slightly less than the calculated total if enough drops of water our left in the other cylinder; however, the mixture should be the same or very close to the same as the calculation. Students should record their observations.

A. The mixture had a greater volume than expected (higher than my calculation).

- *Ask students if they can think of what may have caused this. Suggest they may need to make careful measurements.*

B. The mixture had a lower volume than expected (lower than my calculation).

- *Are there reasons that could account for this? Drops on side not being measured?*

C. The volume of the mixture was what I expected (equal to my calculation).

This is a nice opportunity for students to demonstrate and develop skills related to SEP #3 Planning and Carrying Out Investigatons. this part of the investigation surfaces student undertanding of experimental design, and how unexpected results can be used to reflect on the experiment itself. Throughout this investigation, assessment and instruction are blended: there are several examples of student learning experiences that serve to both develop student understanding while simultaneously offering opportunities for both teachers and students to monitor student progress and learning.

SEPs

ACTIVITY 3.2: DOES 5 + 5 ALWAYS EQUAL 10? (CONTINUED)

ACTIVITY 3.2

4. How does the observed volume of the ethanol/ethanol mixture compare with the total volume you calculated?

A. The mixture had a greater volume than expected (higher than my calculation).

B. The mixture had a lower volume than expected (lower than my calculation).

C. The volume of the mixture was what I expected (equal to my calculation).

Student responses: If measurements were recorded carefully and all of the liquid was transferred into the same container, the measured volume of the mixture should equal or be very close to the calculated amount. Students should record their actual results.

A. The mixture had a greater volume than expected (higher than my calculation).

- *Double-check your calculations and measurements.*

B. The mixture had a lower volume than expected (lower than my calculation).

- *Double-check your calculations and measurements.*
- *Are there reasons that could account for this? Drops on side not being measured?*

C. The volume of the mixture was what I expected (equal to my calculation).

5. How does the observed volume of the water/ethanol mixture compare with the total volume you calculated?

A. The mixture had a greater volume than expected (higher than my calculation).

B. The mixture had a lower volume than expected (lower than my calculation).

C. The volume of the mixture was what I expected (equal to my calculation).

The task uses multiple-choice prompts to conduct a quick process check — these prompts do not assess the NGSS dimensions, they assess whether or not students make key observations of the phenomenon, as they are the basis for the rest of the task. The teacher's guide provides suggestions to the teachers for how they can use incorrect answers to diagnose the problem that the students are likely having.

CONNECTION TO ASSESSMENT PURPOSE

Supplemental content: Water and ethanol molecules have different sizes and shapes, so when they are mixed together, they pack more efficiently and have less overall empty space between the molecules. This causes the combined volume to be lower than the sum of the two liquids being mixed together. Generally, when water and ethanol mix about 5% of the volume is lost, so 5 mL of water and 5 mL of ethanol will produce about 9.5 mL of mixture.

Clarification — This question is just to record students' actual observations which may be different due to procedural errors.

Student responses:

A. The mixture had a greater volume than expected (higher than my calculation).

- *Double-check your calculations and measurements.*

B. The mixture had a lower volume than expected (lower than my calculation).

C. The volume of the mixture was what I expected (equal to my calculation).

- *Double-check your calculations and measurements.*

ACTIVITY 3.2: DOES 5 + 5 ALWAYS EQUAL 10? (CONTINUED)

ACTIVITY 3.2

Discussion

Have students place their results on the board, so everyone can see the class data. You may also or alternatively present student answers to the previous questions using the teacher report which will summarize the results using histograms that will help show the trend in overall observations.

Possible questions:

- What patterns do you see?
- Why do you think the water and ethanol mixture takes up less space than the separate liquids?

This provides authentic opportunities for students to develop and use the CCC patterns by asking students to make observations of the patterns they see in the results of the experiment across the classroom. The crosscutting concept is used to help them understand the phenomenon, and it moves to the background in the later parts of the task when students focus on explaining the phenomenon using the SEP and DCI. The students are unlikely to have the knowledge needed to explain the pattern at this point in the activity, so the assessment is one dimensional, but is used strategically in sequencing the task. This is an example of students developing the idea of patterns, but also assesses whether students have developed and understanding of patterns at the level expected from early elementary school.

Patterns are used at a lower level of sophistication than 6-8 elements of the CCC suggest, but the students' identification and discussion of patterns in the phenomenon is productive, useful, and relevant to the task.

SCENARIOS | CCCs

CONNECTION TO ASSESSMENT PURPOSE

Tip: Students might say that evaporation or drops left in the other graduated cylinder or on the stopper could account for the loss in volume when the ethanol and water were mixed. This is a good hypothesis that should be tested. It can be tested by doing a demonstration that involves measuring the mass of water and ethanol before mixing and the total mass of the mixture. Alternatively, students can add drops of water until the volume adds up, and then determine if it is likely that much water was stuck to the other cylinder. Students should see that the loss in mass due to drops sticking to the other cylinder is significantly less than the loss in volume of the mixture. If you have students do this, make sure they use stoppers while recording the masses, because ethanol evaporates quickly.

This could be a good opportunity to discuss scientific methods. Ask students how they can test whether or not evaporation is the cause.

ACTIVITY 3.2: DOES 5 + 5 ALWAYS EQUAL 10? (CONTINUED)

ACTIVITY 3.2

6. What patterns do you see in the class data regarding observations of mixing water + water, ethanol + ethanol, and water + ethanol.

Supplemental content: When the liquids are the same, the volume of the mixture is the same as the total calculated by adding the original volumes. However, when the water and ethanol are mixed, the volume is not the same as the calculated total. It is less. This is due to the fact that the molecules can pack more efficiently when the shapes and sizes of the molecules differ from each other.

Clarification — Students are not expected to provide a mechanism here.

Student responses: Students should have a general description of the patterns. They should come to a consensus as a class on the patterns.

- Water and water and ethanol and ethanol added up as expected, but water and ethanol was less than the calculated amount.
- I always find there is less than I calculated.
  - *Make sure students are using the class data and not their individual observations.*
- They are all different
  - *Help students identify patterns in the class data. What is similar? This may be an opportunity to discuss experimental error to reach a consensus on what is acceptable variation and what is a real difference in volume.*
- I sometimes find more than calculated.
  - *Ask if this is a common observation in the class data. What is the pattern?*

ACTIVITY 3.2: DOES 5 + 5 ALWAYS EQUAL 10? (CONTINUED)

ACTIVITY 3.2

7. [drawing prompt] Draw a model that explains the volume you observed after mixing the water and ethanol. You can use the particle model, continuous model, or your own model—whichever model you think best explains your observations.

[text prompt] Explain your model.

The phenomenon students are explaining is extremely simple and observable, but the science concepts used to explain it are unintuitive; this creates an ideal platform for building new science knowledge related to the DCI but keeping the phenomenon they are focusing on simple and explainable with the DCI. Students do need to know that ethanol and water have different sized molecules to explain the phenomenon, so it's unlikely that they really have the tools to develop these early models, which could be frustrating, but subsequent activities will support students in inferring this fact.

This task also gives students choice in how they approach modeling — using given models or creating their own. This connects to SEP #2 Developing and Using Models, and provides students with scaffolds that can support moving toward developing their own models with confidence.

DCIs | SCENARIOS | EQUITY | SEPs

Water
Ethanol
Mixture

ACTIVITY 3.2: DOES 5 + 5 ALWAYS EQUAL 10? (CONTINUED)

ACTIVITY 3.2

Student responses: Students are still developing an explanation for this phenomenon. They are not expected to have developed a consensus at this point.

- Students may draw water molecules or other particles to show the two substances mixing.
- Students may draw an image of the experiment or a macro-scale diagram representing their observations.
    - *Ask students if this fits a definition of the models.*

Students respond to prompts designed to be used as formative assessment opportunities integrated throughout the task. These take different forms, from multiple-choice, discussions, written responses, and models. In this example, students develop an early model to explain the phenomenon they are investigating, providing information to the teacher about their ideas about the DCI and their ability to represent them with the SEP. The teacher's guide provides varying levels of information about what teachers should look for in students' responses and ideas, interpret what they mean for the student's progress with the dimensions being assessed, and advise how they might address areas of need. It is unusual for curriculum materials to provide this degree of attention to the benefits of continually making students' progress with the learning goals visible.

These resources would be even more helpful if the guidance about how to use student responses to inform instructional steps were more substantive. In this case, if students are not accurately representing two substances mixing, the instructions are to ask them if their model fits the definition of a model. At this point, there may be several things students are struggling with, such as understanding what a particulate view of a mixture might look like, not just knowing how to model it. The advice does not address ways to recognize problems with both dimensions and how to attend to them.

SEPs | DCIs

CONNECTION TO ASSESSMENT PURPOSE

Revisiting the Driving Question

Display a variety of students' or groups' models. Ask students to evaluate the relationship between each model and their observations of the volume when water and ethanol were mixed.

Possible questions:

- *How does this model explain the change in volume?*
- *What patterns do you see when comparing these models? Are there similarities or differences in how students (or groups) accounted for the change in volume?*

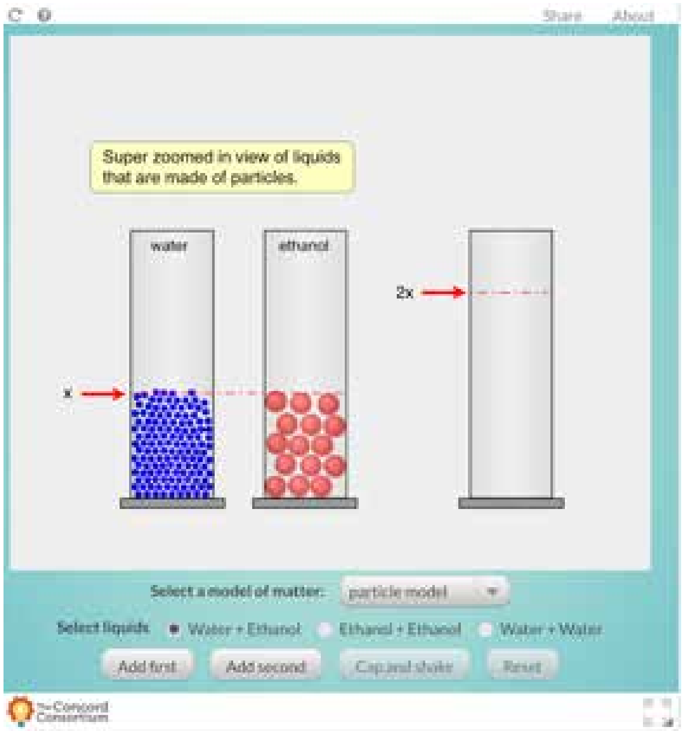
ACTIVITY 3.2: DOES 5 + 5 ALWAYS EQUAL 10? (CONTINUED)

ACTIVITY 3.2

PAGE TITLE:

COMPUTER SIMULATION

In science, a model is considered useful if it can explain observations. The following simulation will provide more evidence to help you decide whether the continuous model or particle model provides a better explanation for your observations of mixing liquids.



Students are given multiple opportunities to engage with the phenomenon in distinct ways, including an experiment in which they get their own experience with the phenomenon, a simulation that they can use to connect the DCI to the phenomenon, and a demo in which they see an alternate representation of the phenomenon at a larger scale. Having several very different representations of the phenomenon can support students who are struggling with sense-making about the phenomenon to see it from a different perspective.

SCENARIOS | EQUITY | SENSE-MAKING

Simulation link: http://lab.concord.org/interactives.html#interactives/interactions/Mixing-polar-nonpolarparticle.json

Try simulating the experiments you did with mixing liquids. Be sure to try both the particle model and continuous model options.

8. Which model better matches the observations you made when mixing real liquids?

A. The particle model.

B. The continuous model.

ACTIVITY 3.2: DOES 5 + 5 ALWAYS EQUAL 10? (CONTINUED)

ACTIVITY 3.2

9. Explain why you chose the particle or continuous model in the previous question.

Student responses:

A. The results matched my experiment.

- *Provide more details. Be specific. Perhaps explain why you didn't choose the other model.*

B. The continuous model looks more like liquids.

- *Ask if their experiment shows the same mixing pattern as expected for the continuous model. Look back at the class data, which should have shown a reduced combined volume for water and ethanol. This contradicts what the continuous model predicts.*

10. Use your observations of the simulation to explain why mixing ethanol and water results in a measured, combined volume that is less than the sum of the original volumes.

Student responses: We are still looking to provide evidence here for one of the models of matter. In the next activity they will gather more evidence for the particle model, so it is OK if consensus has not been reached yet on which one is better at explaining phenomena. If it seems that everyone has decided it is the particle model, then talk about how the model should work for other phenomena.

- The smaller particles can fill in between the gaps between smaller particles.

Many of the prompts in this task are single dimensional, but they serve as useful scaffolds toward meaningful use of the two dimensions together in the following questions. In contrast with Q7, this provides more guidance about addressing evidence of areas of struggle with multiple dimensions based on students' response.

SEPs DCIs

CONNECTION TO ASSESSMENT PURPOSE

ACTIVITY 3.2: DOES 5 + 5 ALWAYS EQUAL 10? (CONTINUED)

ACTIVITY 3.2

Demonstration

Understanding that the packing of two different sized particles can be more efficient when mixed together is difficult for students. A demonstration that helps get this point across is the mixing of sand and some larger "particles" like marbles.

1. Get two identical graduated cylinders (50 mL or greater) and fill one halfway with sand, and one halfway with marbles.
2. Have a student measure the volume of each one and put that on the board.
3. Then sum the two volumes and show the answer.
4. Ask the students to predict what they think the measurement of the mixture will be.
5. Pour the sand into the cylinder with the marbles. And put the combined measurement on the board. It should be significantly less than the sum of the two separate volumes.

Possible questions:

- *Was the combined volume what you expected it to be? Why?*
- *How does this help explain what you observed in the model?*
- *How might this help explain what you observed when you mixed real liquids?*

11. Revisit the model of mixing water and ethanol that you drew after the hands-on experiment. Do the components in that initial model explain your observations of water and ethanol? If not, what revisions would you make to your model?

Student responses: Students will likely have started with a wide variety of models. The key point is to see if they can apply their models to the observed phenomena. Use the following discussion to review student models and how they might need to be updated to account for the shrinking volume of some mixed liquids.

- I had particles before and the particles can explain why the liquid volume decreases because the particles fill in spaces between other particles.
- I did not include particles before, but particles explain why the volume changes because the particles can pack tighter together.

Students repeatedly return to their models to incorporate the new ideas about explaining the phenomenon that may come from interacting with a new representation of it. The process of repeatedly returning to the models gives students ample time to wonder, figure out, and refine before they present their final model to the class. The student's ideas about refining their original model provide evidence to the student and teacher about their progress with the SEP and the DCI.

SEPs SENSE-MAKING DCIs

ACTIVITY 3.2: DOES 5 + 5 ALWAYS EQUAL 10? (CONTINUED)

ACTIVITY 3.2

DQ

Revisiting the Driving Question
Display students' models from Question 7 (just before the simulation).

Discuss and compare the different models. Ask students what changes they would make to the models in light of their new evidence and begin to develop a consensus about the nature of matter.

Possible questions:

- *What do you notice looking across the models?*
- *How are they similar? How are they different?*
- *What do you think is being represented here (referring to specific models)?*

Once students have observed and discussed various aspects of the different models, ask them to start to evaluate which ones best account for the observations of mixing water and ethanol.

Possible questions:

- *What would you change about these models at this point?*
- *What evidence can we use to improve these models?*
- *Which models best explain our observations?*

As students work toward coming to an agreement about which model best explains their observations of mixing water and ethanol, as well as of the simulation, make sure they base their critiques and arguments on evidence from these observations.

The task also makes use of discourse as an authentic way to engage the science practices of comparing and critiquing a models' fit for explaining a phenomenon. In the previous question students had a chance to consider by themselves their own model's fit and need for revision, and this whole-class discussion provides an opportunity for students to learn from each other, hear each other's reasoning, and refine their own thinking through guided discourse with their peers, providing an additional support for all learners.

EQUITY

This task authentically uses several different elements of a dimension. In this discussion students are prompted to discuss patterns in the models, compare and critique models, and consider which of several models best explains the observed phenomenon (connections to several MS SEP #2 elements as well as parts of MS SEP #7 Engaging in Argument from Evidence elements). This portion of the task surfaces students understanding and ability to use SEPs and DCIs to make sense of the phenomenon at a wide range of sophistication, providing a nice example of how SEPs can be used as sense-making tools. While CCCs may implicitly be present when students are comparing models, this does not surface evidence of whether students understand and can use the CCCs.

CCCs **DCIs** **SENSE-MAKING** **SEPs**

ACTIVITY 3.2: DOES 5 + 5 ALWAYS EQUAL 10? (CONTINUED)

ACTIVITY 3.2

DQ

Through this discussion, students should come to the consensus that the particle model best explains their observations of mixing water and ethanol. Have the class select representative models to post on the class driving question board.

Once students agree that the particle model best explains their observations of mixing water and ethanol, ask if the particle model is always best or just in the case of mixing water and ethanol.

Possible questions:

- *If water is made of particles, why is the actual volume of mixing water with water the same as the total calculated by adding the original volumes?*
- *Is the particle model always better than the continuous model? Think about how matter behaves. Can the particle model explain other phenomena?*

If students are still not convinced that the volume of the mixture of ethanol and water is less than the total of the original volumes, you can display the computer simulation and discuss students' observations of mixing water and water or ethanol and ethanol.

This task also provides students the opportunity to develop demonstrate their current understanding, through discussion, a critical nuance to understanding the SEP — that the fit of a model depends on the phenomenon being modeled.

SEPs

Homework: Worksheet for Activity 3.2

Models of Water and Ethanol