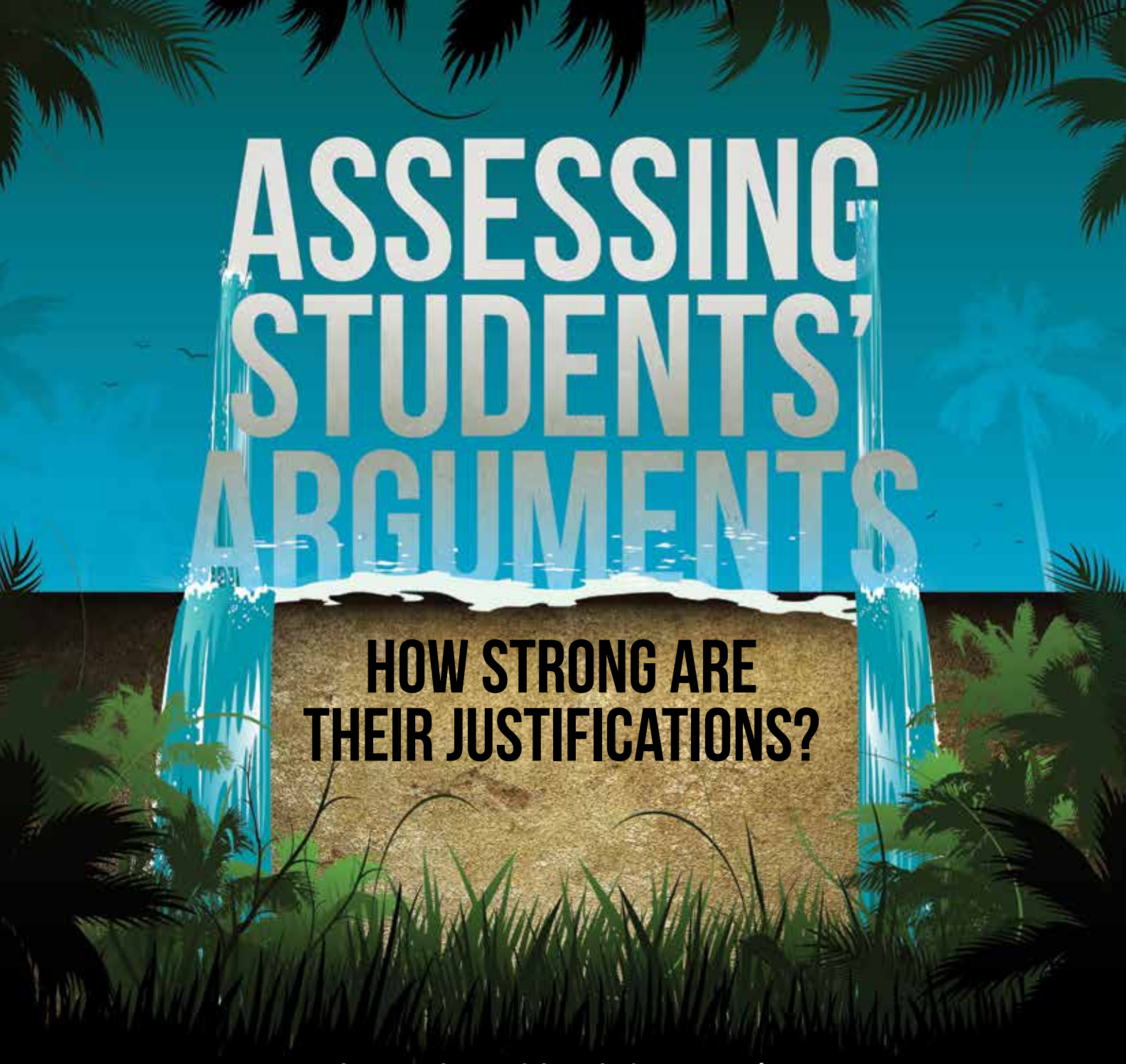


ASSESSING STUDENTS' ARGUMENTS

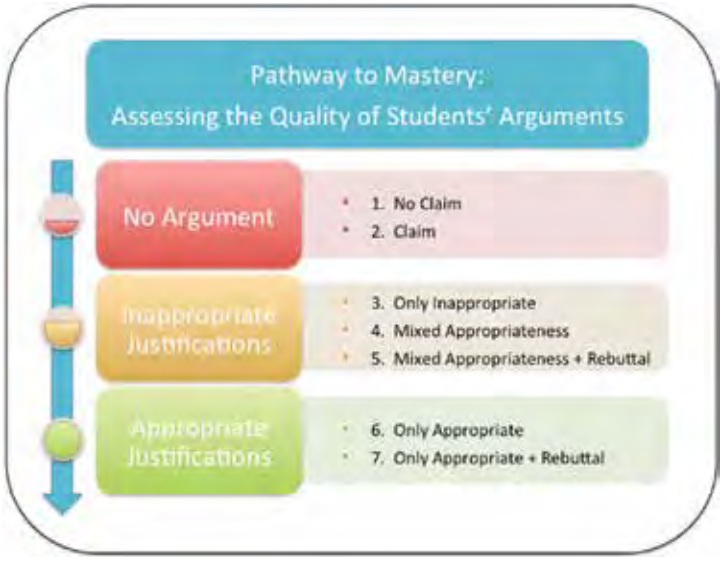
HOW STRONG ARE THEIR JUSTIFICATIONS?

by Amanda M. Knight and Kris Grymonpré

On most days, Sally sits quietly in her seventh-grade science class, overwhelmed by the thought of raising her hand to participate in the discussion. Sally, who has Asperger's syndrome, has never talked in front of a class. But today she confidently walks up to the front of the room and presents her argument about why the Brazilian government should not build the Belo Monte Dam. Sally, who represents an indigenous Brazilian tribe in this activity, justifies her argument with evidence, detailing how the dam would negatively affect the Kayapo people. She doesn't miss a beat responding to questions from other students, who play other roles in the controversy.

FIGURE 1 Checklist to assess the quality of students' arguments

FIGURE 2 Pathway to mastery



Sally is prepared and has a purpose: to persuade other students that her claim is correct. Preparing for the debate, she collected evidence from readings and videos, and organized that evidence into an effective argument. Her teacher (Grymonpré) checked in informally to make sure her claim had appropriate justifications. Her hard work is evident when she presents. Sally offers up the following:

> This will be a devastating blow for the 10,000 tribal Indians whose lives have changed little since the arrival of Europeans five centuries ago. We, the Kayapo people, live beside the river, and the dam will bring an end to our way of life. The effect will be catastrophic and push us deeper into poverty, just as it did for the 40,000 people displaced by the Tucuruí Dam in the 1980s.

In her closing statement, Sally appeals to her classmates' hearts: "This is the second time we're fighting this battle. Yet you still ignore us like we're helpless animals or something. Why can't you respect us?" Her connection to the argument is so powerful that the class "ooohs" in unison.

Although we changed the student's name and some details to protect her identity, this example is based on an actual science lesson from the second author's (Grymonpré's) classroom. We have worked together over the last four years to support students in this type of argumentation; the students' arguments we present in this article occurred during the last two months of an academic year. These students attend an urban public school and have diverse backgrounds and abilities, which we supported with multiple means of engagement (e.g., everyday, scientific, and socio-scientific examples), representations (e.g., using graphic organizers, modeling, constructing their own arguments, and critiquing others' arguments), and expressions (e.g., reading, writing, and talking) as well as individual check-ins and constant feedback. One element we have found to be very important is that teachers must be aware of their students' progress toward constructing effective arguments. While Grymonpré did an excellent job of supporting his students, including Sally, in the development of their argumentation abilities, this is a skill that he developed over time and one that he continues to refine. Based on what we learned from this lesson, we worked together to develop a checklist that will help teachers to assess the quality of their students' arguments (Figure 1). The checklist can also be given directly to students to emphasize what they should consider when constructing their arguments. In this way, more teachers will be able to support students like Grymonpré supported Sally.

FIGURE 3 Proposed location of the Belo Monte Dam

MATTHEW PIKE

What is an argument?

Scientists build knowledge through the debate of claims and the evidence that is used to support them. Following this pattern, theories are rebutted and revised when new ideas are proposed. Yet any teacher knows that students, too, can argue. The challenge is getting them to argue using the scientific norms of evidence and reasoning. This challenge is worth surmounting, because doing so provides opportunities for students to clarify and expand on their science ideas and makes visible their scientific thinking and reasoning.

To help students express their arguments, we use a framework that simplifies this complex prac-

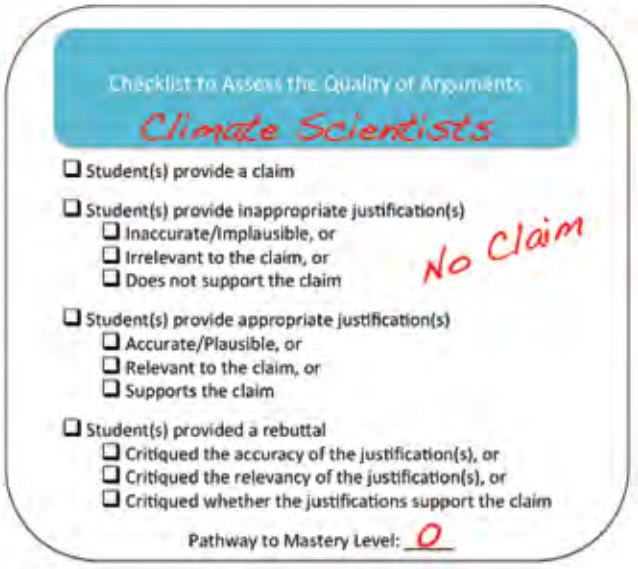
PHOTOS COURTESY OF THE AUTHORS

Students presenting their initial argument during the debate.

FIGURE 4 Transcript of climate-scientist group's oral arguments

Ike:	And we are the climate scientists. Um, I feel like the dam will cause global warming because when the dam floods for the first time, when you guys build it, it will rise and all the fish and all the animals inside the water will be left [inaudible] and within several months they will rot away and hurt all the dirt on the ground.
Adriana:	Methane is produced when the vegetation decomposes at the bottom of the reservoir. The actual reservoir produces 23 million tons of carbon dioxide and 140,000 tons of methane. Methane, like carbon dioxide, is a greenhouse gas that gets trapped in the Earth's atmosphere, contributing to global warming. Glaciers [are] gone now because of global warming.
Jada:	So dams are taking a huge part of global warming. If pollution keeps happening like this, in 50 years, Massachusetts will be as warm as South Carolina.
Aisha:	Dams on the Earth say hydroelectrics is pollution-free, but they ignore how the reservoir produces a lot of methane. They all basically try to hide these things.
Ike:	The dam also lets off greenhouse gases, and one really bad greenhouse gas is called methane. And what this gas can do is allow people to get cancer and [inaudible]. One of my main concerns is what the greenhouse gas from the dams is going to do to the kids around.
Jada:	Cutting down the trees and making roads so loggers could come in and cut down the trees is bad. If we don't have any trees, the oxygen is going to get low, and people will eventually have a hard time breathing and die.
Aisha:	There are definitely pros and cons for this. The pro is that people are doing it to get electricity in Brazil. But the con is people that live there will be losing their homes that they live [in], probably all of their land.

FIGURE 5 Checklist to assess climate-scientist group's oral argument



tice by emphasizing the structure of an argument. Specifically, the framework breaks an argument into the components of the claim and its justifications (McNeill and Krajcik 2012). A *claim* is a statement that answers a question. *Justifications* are used to support the claim, and their quality is measured in terms of appropriateness and sufficiency. We emphasize two forms of justification: evidence and reasoning. Whereas *evidence* consists of empirical data that support the claim, *reasoning* uses scientific principles or ideas to explain how or why the evidence does so. A *rebuttal* critiques the justifications for an alternative explanation. Middle school students should be able to construct justified claims, both orally and in writing, as well as rebut justifications for counterarguments. However, the quality of students' arguments may differ across these two forms of expression.

What makes some arguments more sophisticated than others?

Assessing the quality of arguments, either spoken or written, is not an easy task. For instance, there are often numerous aspects of students' writing that could be addressed, but it is difficult to know which are the most important. The in-the-moment appraisal required of spoken arguments can be even more difficult, because teachers need to make a quick assessment. This challenge is further compounded by the need to monitor students' progress over time.

Students working together to prepare their arguments.

To help address this pedagogical challenge, we present a pathway of students' abilities as they progress toward mastery of this scientific practice (see Figure 2). The pathway includes benchmarks, such as using appropriate justifications and providing rebuttals. Because the benchmarks are applicable to both forms of communication, the pathway can be used to compare the quality of students' oral and written arguments and track their development over time. At the lower levels of the pathway, students fail to construct an argument because they either do not provide a claim or do not justify their claim. Within the intermediate levels, students justify their claim, but they include inappropriate justifications. Justifications are inappropriate if they are conceptually inaccurate or irrelevant to the claim or contradict the claim. In comparison, at the highest levels of understanding, students use only appropriate justifications. It is at these levels that students approach mastery of the practice.

Teachers need to quickly and accurately decide where their students' arguments fall along the pathway. To aide this process, we present a checklist that tracks benchmarks as they are satisfied (see Figure 1). It can be used when grading written arguments as well as when listening to oral arguments during classroom discussions. The checklist can later be compared to the pathway to determine the quality of students' arguments.

FIGURE 6 Transcript of the Kayapo-tribe group's oral argument

Macarius: We are the Kayapo tribe. We the Kayapo tribe oppose the building of the Belo Monte Dam.

Zander: People have tried to prevent the Belo Monte Dam from getting built. In 2001, six people died because they were anti-activists and people and they were risking their lives to protect their land and their people.

Mr. G: Why were they hurt?

Zander: Because they were, they were trying to prevent the dam from getting built, and if the dam is built it will take our food sources, our transportation [inaudible]. We cannot feed a 130-kilometer stretch of people without water, food, or transportation.

Sally: This will be a devastating blow for the 10,000 tribal Indians whose lives have changed little since the arrival of Europeans five centuries ago. We, the Kayapo people, live beside the river, and the dam will bring an end to our way of life. The effect will be catastrophic and push us deeper into poverty, just as it did the 40,000 people displaced by the Tucuruí Dam in the 1980s.

Ochen: There are approximately 100 dams being planned for the Amazon rain forest. We are not getting any proceeds from these dams. And when the Belo Monte Dam is built they are redirecting the river so that it [bypasses] the Kayapo tribe.

Mr. G: Can you say that one more time? Do you need to draw it out or something? What do you mean?

Ochen: [drawing] Say this is the river. And we live in the area. If the dam is being built, the people, they will move the river in this direction [indicating in his drawing that the river would be circumventing where the Kayapo currently live along the river].

Zander: They'd be taking all of our water.

Mr. G: Why do you guys need that water?

Sally: Fishing.

Zander: For fishing, transportation, and water.

Macarius: Basically for everything we need to survive. Um, we've been fighting the Belo Monte Dam for 20 years, but right now no one is listening to us. The Belo Monte Dam will flood 400 square kilometers of land from us. This is equal to 40,000 football fields. It's way bigger than Cambridge, Massachusetts. Questions?

What follows are an example of a socio-scientific argument and a scientific argument. Both examples demonstrate how the checklist and pathway to mastery can help a teacher quickly and effectively assess the quality of socio-scientific and scientific arguments as well as both spoken and written arguments.

Socio-scientific example: Belo Monte Dam

Unit summary

We designed a unit to help students develop written and oral arguments about the construction of the Belo Monte Dam along the Xingu River, a tributary of the Amazon River, in Brazil (see Figure 3). While the dam's builders promise that it will provide clean energy, it will also displace a disempowered people and cause ecological damage. The dam was officially granted a construction license in 2011, and construction has recently begun. However, many indigenous people and local communities are actively occupying the construction site, and there are also several ongoing legal challenges to prevent Belo Monte from diverting the Xingu River. Prior to this unit, Grymonpré's class had studied the physics of how hydroelectric dams generate electricity, and students had raised and released wild Atlantic salmon, which are endangered in part because of dams on their native rivers. Students had enough background knowledge to become motivated about the issue. Middle school students generally become fired up when

FIGURE 7 Checklist to assess Kayapo-tribe group's oral argument

FIGURE 8 Akil's written argument about the Belo Monte Dam

I think this Dam shouldn't be built because of the animals, medicines from plants and trees, and the methane gas the reservoir produces. Animals are going to die because this dam is taken over a lot of land. The animals will go extinct because that's the only place where you can find certain animals like the ones in the Amazon Rainforest. The reservoir next to the dam will produce methane from decomposed species. This makes our world overheat. Most of Antarctica will melt if methane is produced. It can also make people severely sick and they can die. Then, over 40,000 football fields of land is going to be flooded by the reservoir, which means trees and plants can't grow and will die. We need those plants and trees because it produces medicines to cure our sicknesses. A person that disagrees with me could argue that the Dam is a good thing because it produces electricity for the country of Brazil. I would respond by saying the electricity doesn't even go to the people in Brazil that need it. It goes to aluminum smelting factories that produce even more pollution to our world. Building this Dam is going to be a bad idea for Brazil because the electricity doesn't go where people think it's going and the animals and trees it kills and the methane it produces.

FIGURE 9 Checklist to assess Akil's written argument

discussing fair outcomes, especially when given the opportunity to persuade others.

The class was divided into role-based teams: Hydrologists studied the best placement for a hydroelectric dam; the power company realized the need for more electricity; the Kayapo people lived near the proposed site; climate scientists studied the environmental impact of building a large dam; and ecologists studied the dam's impact on the Amazon rain forest. Using news articles and websites as sources, we created a reading for each group that reflected the biased perspective of the specific role group. Each group had exclusive access to the vital information for its role. Because the real-life scenario is so complicated, we felt that it would be overwhelming to provide students with all of the information from every group. For example, students in the Kayapo group had a clearer understanding of the impact of the dam on their way of life, limiting their access to food, water, and transportation. Other groups understood that while much of the river was being diverted, water would still flow through the Kayapo land.

In the week prior to the debate, students completed a structured note-taking worksheet in which they made a claim, listed evidence from the reading, and later explained why each piece of evidence supported the claim. Because of the socio-scientific context, students used a range of evidence (i.e., it included scientific, ethical, political, and moral influences)

to help them justify their arguments. In preparation for the debate, each group developed an argument based on its notes, predicted other groups' arguments, and generated a rebuttal for those that would likely disagree. For the debate itself, each group made an opening statement in which the group presented its claim and justifications. Next, other groups asked the presenting group questions or challenged the presenters' evidence. Finally, each group gave a closing statement. Following the debate, students individually wrote an argument representing their personal perspective. They used the research from their oral arguments and justifications presented by other groups. The environmental-justice issue, presented in this format, motivated students to prepare strong arguments as well as to engage in the material and in discussion with each other.

Assessing the quality of students' arguments

To assess the quality of students' spoken and written arguments, we used the checklist and pathway to mastery (Figures 1 and 2). For instance, in their oral argument, which is presented in Figure 4, the climate scientists describe the situation nicely. However, they never present a claim, and they actually summarize both points of view, in the very last sentence, without taking a stance. Because they did not present a claim, none of the descrip-

FIGURE 10 Density lab data sheet

Liquid	Mass of Graduated Cylinder	Mass of Graduated Cylinder + Liquid	Mass of Liquid	Volume of Liquid	Density
Red	15.4g	75.1g	59.7g	58mL	1.03 g/mL
Blue	15.4g	97.6g	82.2g	83mL	0.99 g/mL
Green	15.4g	77.9g	62.5g	60mL	1.04 g/mL
Yellow	15.4g	103.9g	88.5g	88mL	1.01 g/mL
Purple	15.4g	104.8g	89.4g	84mL	1.06 g/mL

Because these liquids will try to mix together, the experiment will only work if you pour the liquids in the correct order. Draw your prediction below. As always, label the liquids with their densities.

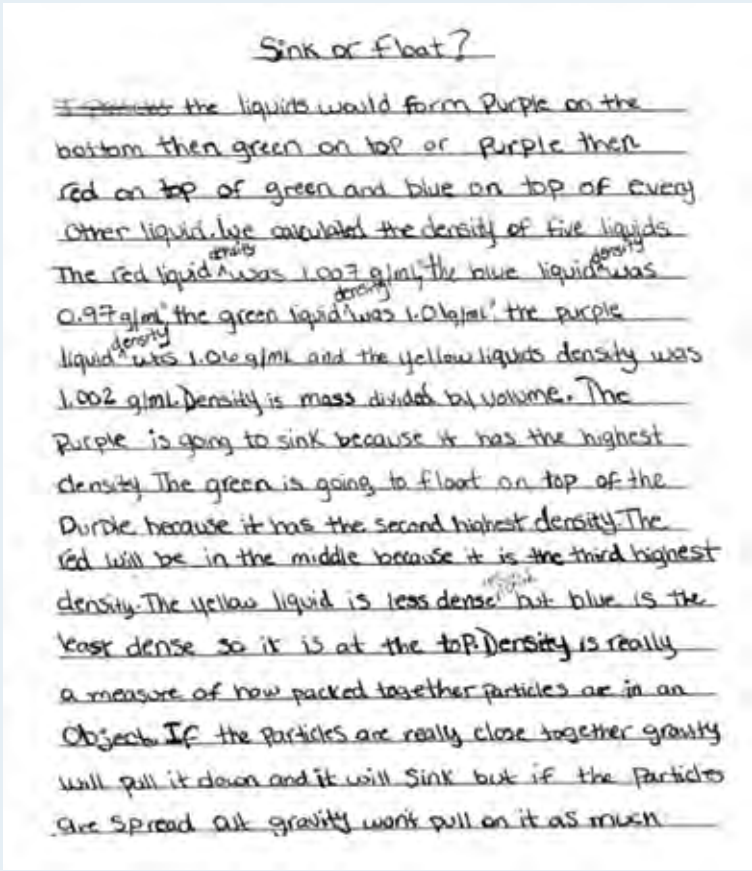
Blue	0.99 g/mL
Yellow	1.01 g/mL
red	1.03 g/mL
green	1.04 g/mL
Purple	1.06 g/mL

tions can count as justifications, as there was nothing to justify. These students, therefore, did not construct an argument. The lack of benchmarks met is reflected on the checklist (see Figure 5). In comparing the checklist to the pathway to mastery, we see that this argument corresponds to level 0. It should, however, be noted that our checklist was developed using the student arguments from this lesson. If it was available in the moment students were constructing their arguments, it would have helped both the teacher and students focus on ensuring that students stated their claim. In both previous and subsequent arguments, these students did provide a claim in both oral and written arguments, which suggests that they may have overlooked the persuasive purpose as opposed to not knowing how to construct a claim. Regardless, this non-argument can be compared to the quality of the Kayapo tribe's oral argument (see Figure 6).

Using the checklist (see Figure 7), we note that these students provided a claim and limited their justifications to those that were solely appropriate. They, however, did not rebut the other perspectives; as such, their argument was at level 6 on the pathway to mastery.

Finally, we look at Akil's written argument (see Figure 8). Akil argued that the Belo Monte Dam should not be built and provided both appropriate and inappropriate justifications. For instance, he inappropriately justified that "most of Antarctica will melt if methane is produced" and "it can also make people severely sick and they can die." However, he provided a strong rebuttal by critiquing how the newly generated electricity would be distributed. The checklist (see Figure 9) summarizes the benchmarks that he satisfied, and when compared to the pathway to mastery, we see that his argument corresponds to level 5.

FIGURE 11 Jasmine's written argument about density


Sink or float?

I ~~believe~~ the liquids would form Purple on the bottom then green on top or Purple then red on top of green and blue on top of every other liquid. Ive calculated the density of five liquids. The red liquid's density was 1.007 g/ml, the blue liquid's density was 0.97 g/ml, the green liquid's density was 1.01 g/ml, the purple liquid's density was 1.016 g/ml and the yellow liquids density was 1.002 g/ml. Density is mass divided by volume. The Purple is going to sink because it has the highest density. The green is going to float on top of the Purple because it has the second highest density. The red will be in the middle because it is the third highest density. The yellow liquid is less dense but blue is the least dense so it is at the top. Density is really a measure of how packed together particles are in an Object. If the particles are really close together gravity will pull it down and it will sink but if the particles are spread out gravity won't pull on it as much

Scientific example: Density

Lesson summary

In comparison to the Belo Monte Dam unit, in which students used secondary data, in this lesson students collected their own data. Specifically, they measured the mass and volume of five different colored liquids as well as calculated the density of each (see Figure 10). Each student then wrote an argument answering the following question: In what order do you

predict the liquids from the lab will form layers? Lastly, the class performed the investigation to verify whether students' predictions were accurate.

Assessing the quality of students' arguments

Again, we apply the checklist in conjunction with the pathway to mastery to measure the quality of students' arguments. In looking at Jasmine's written argument about density (see Figure 11), we see that she argued that the liquids would layer from bottom to top: purple, green, red, (yellow), and blue. While she forgot to mention yellow in her initial claim, she did clarify where it would fall within the order later in the argument. We also see that all of her justifications are accurate and appropriate, and that she has a sophisticated understanding of density for a seventh-grade student. Because she did not provide a rebuttal, her argument corresponds to a level 6. The checklist (see Figure 12) summarizes the benchmarks she satisfied.

Conclusion

While the Belo Monte Dam unit provided opportunities for students to consider multiple perspectives and engage in argumentation, argumentation lessons need not always be this complicated. Providing opportunities for argumentation can be as simple as having students construct arguments as they make sense of data they collect during investigations. It is, however, imperative that students recognize that they are supposed to convince their audience. Therefore, when providing instructions for argumentation lessons, it is important to set expectations for students to be persuasive by emphasizing support and defense (Reiser, Berland, and Kenyon 2012). For instance, in introducing the Belo Monte Dam debate to his students, Grymonpré said:

> All right, as you're preparing this, figuring out what you're going to say, what's most important, you might think about which facts, now that we've heard all of the evidence, are most important. Think about which arguments you really want to drive home.

Routine engagement in argumentation can be further supported through classroom norms. Specifically, students should know that they are supposed to support their claims with justifications. This means applying the concepts and self-monitoring their quality, as opposed to merely reciting the terms and definitions. For instance, a student might say, "What is your evidence for that?"

FIGURE 12 Checklist to assess Jasmine's written argument

when he or she doesn't trust a claim proposed by another student. A poster listing possible prompts is a great way to remind students of the questions they should consider. Likewise, consistent and effective feedback helps to not only maintain argumentation norms but also support the development of students' argumentation skills. The pathway to mastery and corresponding checklist are tools that can be used to quickly assess the quality of students' spoken and written arguments as well as provide a focus for feedback. ■

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