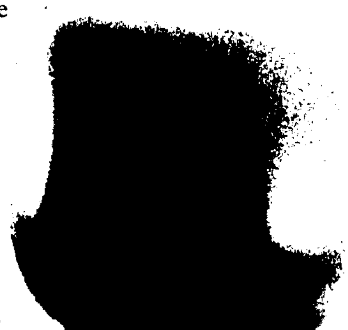
Incorporating Scientific Argumentation into Inquiry-Based Activities with Online Personally Seeded Discussions

by Victor Sampson and Douglas Clark

An explicit goal of the current reform movement in science education is to promote scientific literacy in the United States (AAAS 1993; NRC 1996). One way to encourage scientific literacy is to help students develop a better understanding of science subject matter, that is, the declarative knowledge specifically associated with the physical, life, and earth sciences. However, in addition to helping students develop this type of knowledge, science education programs designed to promote true scientific literacy need to also help learners understand how this knowledge is generated, justified, and evaluated by scientists and how to use such knowledge to engage in inquiry in a way that reflects the practices of the scientific community (Driver, Newton, and Osborne 2000; Duschl and Osborne 2002).



Inquiry is at the heart of current efforts to help students develop this type of scientific literacy (NRC 1996). In this literature, inquiry is described as a knowledge-building process in which explanations are developed to make sense of data and then presented to a community of peers so they can be critiqued, debated, and revised. Thus, the ability to engage in argumentation in order to construct, justify, and evaluate scientific explanations is seen by many as an important component of scientific literacy. Yet opportunities for students to engage in argumentation as part of the inquiry process in science classrooms are rare. Hence, our work focuses on developing new and innovative ways to integrate productive argumentation into the teaching and learning of science.

Online personally seeded discussions

In order to foster productive argumentation in science classrooms, we have developed the personally seeded discussion (PSD). This tool, which is currently embedded into an online science project called *Thermodynamics: Probing Your Surroundings*, is designed to help students learn how to:

- use observations and data in order make sense of a phenomenon under investigation,
- develop and articulate an underlying explanation for the given phenomenon,
- convince others of the validity and usefulness of an explanation by justifying and defending it with scientific evidence and rational reasoning, and
- use empirical and theoretical criteria important to science when assessing the validity or appropriateness of scientific explanation.

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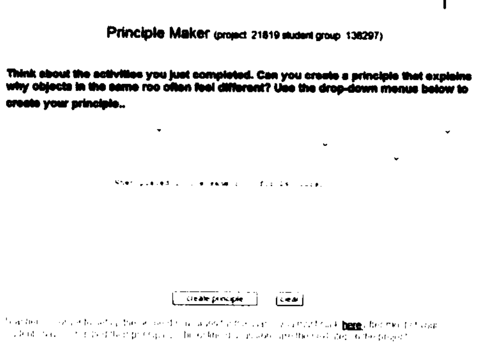
The PSD is an online asynchronous discussion forum that automatically sorts participants into small groups based on the nature of students' ideas. While in this forum, students have an opportunity to propose, justify, critique, and revise their ideas until they reach consensus. For example, in the *Thermodynamics: Probing Your Surroundings* project students are asked to generate a principle that can explain why some objects, such as a metal chair leg and a wooden table, feel like they are different temperatures. Some students suggest that they feel different because they are, in fact, different temperatures. Others suggest that metal "absorbs" cold so it feels cold. Some suggest that it has to do with the conductivity of the object and not the temperature of the object. The PSD software takes advantage of these different ideas in order to foster argumentation. Our software is able to score the ways students explain a particular phenomenon and then uses this information to create online discussion forums that consist of students who have different interpretations of the same phenomenon. When confronted with these different interpretations, students must discuss and debate the validity of each explanation using the data they have gathered in order to reach consensus.

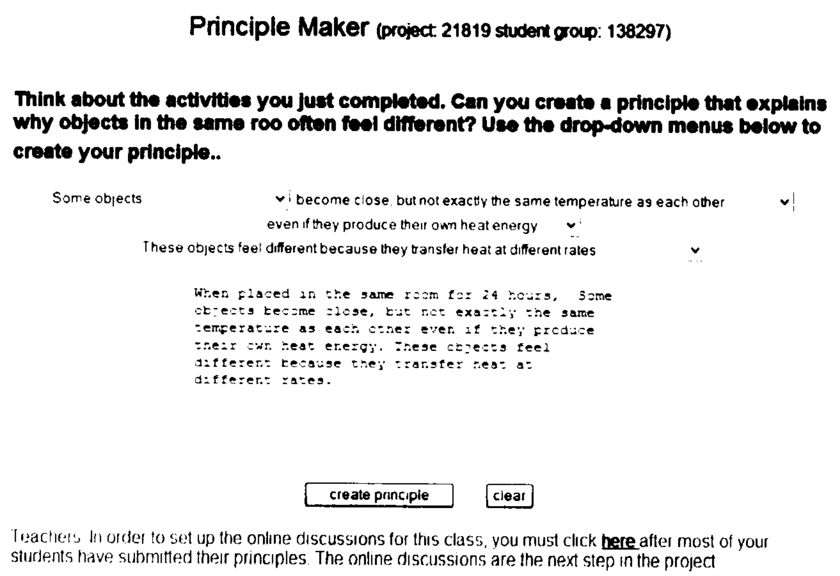
To support this process, students use a specially designed interface to create their initial explanations for the phenomenon under investigation. This interface, which we call *the principle-maker*, allows students to use a pull-down menu format to create an explanation or a principle from sentence fragments (Figure 1). The predefined phrases and elements include inaccurate ideas that students typically use to explain the phenomenon under investigation. The pull-down format ensures that the students' ideas are well elaborated so that other students notice differences and want to discuss them. Once the students have created and submitted their principles, the teacher uses a link on the principle-maker interface to set the number of discussion forums (we suggest one discussion forum for every five students). The software then automatically creates the PSDs based on the principles the students created. Once this step is complete, students are able to enter the online asynchronous discussion forums. The first thing students see is their principle and the principles created by three or four of their classmates (see Figure 2). Students are then directed to read and critique these principles with the goal of reaching consensus.

This type of activity moves beyond simply telling students to evaluate one another's ideas. By asking the students to construct preliminary explanations before joining the discussion we provide students with an opportunity to develop ownership over their ideas. This ownership provides students with intrinsic motivation to defend their explanation (Kuhn and Reiser 2006). In addition, because students must agree upon a single answer, they have to engage with one another's ideas so that they can either weed out inaccurate ideas or combine ideas to produce better explanations. That is, in order to come to consensus, students need to compare their ideas, pay attention to one another as they defend and question each other, and revise their final explanation accordingly. In short, they must engage in argumentation in order to be successful. Thus, this activity structure goes beyond typical small group work. Rather then viewing small group work as an opportunity to divide up the labor in order to finish a task quicker or as an opportunity to rely on a more knowledgeable peer (Cohen 1994; Linn and Burbules 1993), students must engage in genuine collaboration and consensus building.

FIGURE 1

Students use the principle-maker to construct scientific principles that become initial discussion comments within the discussion forum





Using the PSD tool in the classroom

As previously mentioned, the PSD tool is currently embedded into an online science project called *Thermodynamics: Probing Your Surroundings*. This project was developed by the Technology Enhanced Learning in Science (TELS) Center. TELS (*www.telscenter.org*) is one of 15 national Centers for Learning and Teaching established by the National Science Foundation to improve instruction in science, mathematics, and engineering by developing technology-enhanced learning environments. The *Thermodynamics: Probing Your Surroundings* project (along with several other online projects) is available for teachers to use at no cost simply by accessing the WISE website (*http://wise.berkeley.edu*). In order to assist teachers who are interested in using this project (or any of the other projects) in their classroom, comprehensive lesson plans, assessment tools, specific technology requirements, teacher hints, and detailed instructions for setting up and running projects are available through the WISE website.

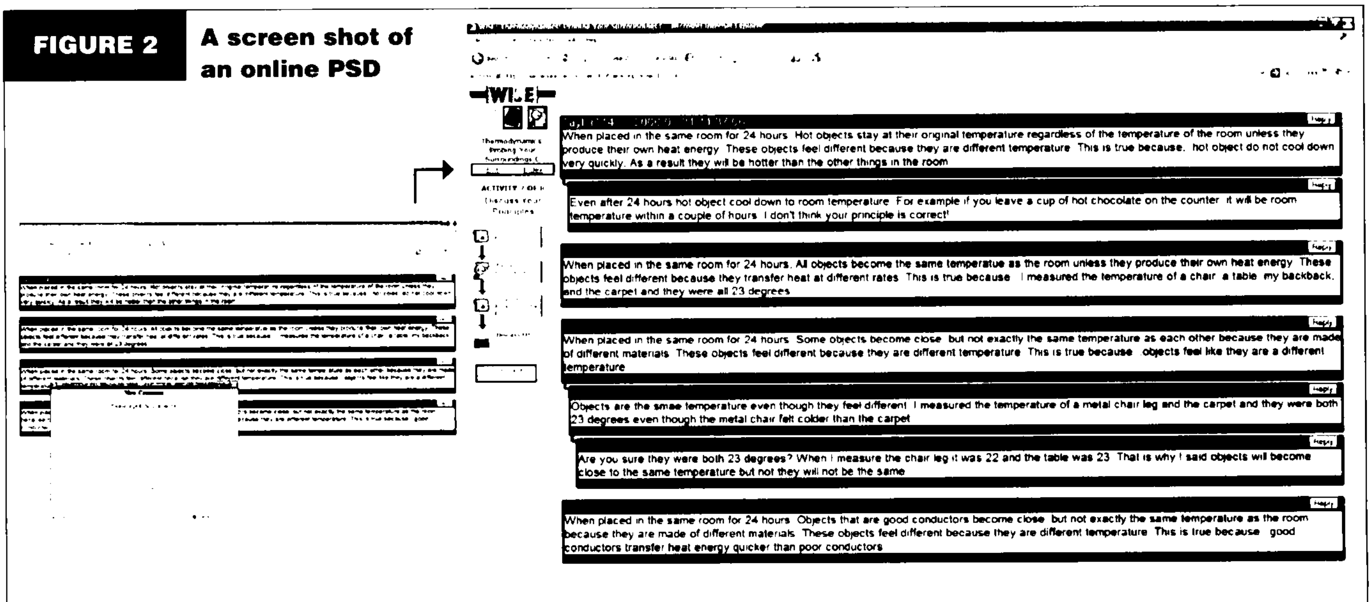
Thermodynamics: Probing Your Surroundings consists of eight activities and takes approximately four 50-minute class periods to complete. In activities 1–5 students collect real time data about the temperatures of objects found inside the classroom and explore interactive simulations dealing with such ideas as heat transfer, thermal conductivity, and thermal sensation (see Figure 3). As students work through these activities they are prompted to record the data they gather and describe the observations they make using the WISE note feature. All student work is automatically saved on the WISE server, so when students log off at the end of a class period, and log back in the next day, they can pick up right where they left off. Together, these five activities are designed to provide students with empirical data and other scientific ideas about the phenomenon under investigation. Students then engage in the PSDs during activities 6 and 7. Finally, in activity 8, students are asked to reflect on what they have learned and to create a final principle that explains why some objects feel like they are different temperatures.

Benefits of using PSDs

Our research (Clark and Sampson, 2005, 2006) indicates that the PSD is an effective way to foster productive argumentation. Students have an opportunity to learn about the ideas of others, respond to the questions and challenges of other students, articulate more substantial warrants for their views, determine ways for distinguishing which of these ideas is the most useful, and eventually reach consensus. PSDs also encourage participants to be more reflective and to make more contributions than in typical face-to-face discussion. More importantly, the PSDs provide teachers with a way to manage student participation and a window into students' thinking by making their ideas and discussions visible. With this information, a teacher can explicitly challenge students' understanding of the nature of scientific knowledge and help students enhance their argumentation skills.

This is important because current research clearly shows that very few K–12 students develop an appropriate understanding of how scientific knowledge develops within the scientific community or the nature of scientific knowledge in general (Lederman 1992; Lederman and Abd-El-Khalick, 1998). Most students view scientific knowledge as static, uncontroversial, and the result of discoveries made by individual scientists, rather than seeing it as tentative, subjective (even though it is empirically based), and socially constructed. These mistaken views often result from students'

FIGURE 2 **A screen shot of an online PSD**



experience of science in the classroom (Clough and Olson 2004). For example, students' only introduction to the nature of science often involves instruction about "the scientific method" as a series of steps that all scientists are said to follow when conducting an investigation (Colburn 2004).

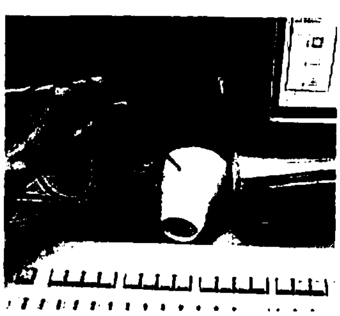
Obviously this depiction of science is not entirely accurate. There is no universal set of steps to which every scientist must adhere during an investigation that begins with "defining the problem" and ends with "reporting the results." Cookbook laboratory activities further reinforce this view of the scientific method. Such activities, which require students to follow a step-by-step method when conducting an experiment, teach students that following procedures during a scientific inquiry will always result in the correct answer, and that a conclusion can easily be made from the data collected. As a result, students often mistakenly believe that the scientific method always produces absolute or "true" knowledge and that scientists' claims can be accepted without question because the findings were "discovered" using the scientific method. Unfortunately, this focus on *what* scientists know at the expense of *how* scientists know, as well as the focus on empirical work as the main (or only) component of scientific inquiry, misrepresents the way science actually operates.

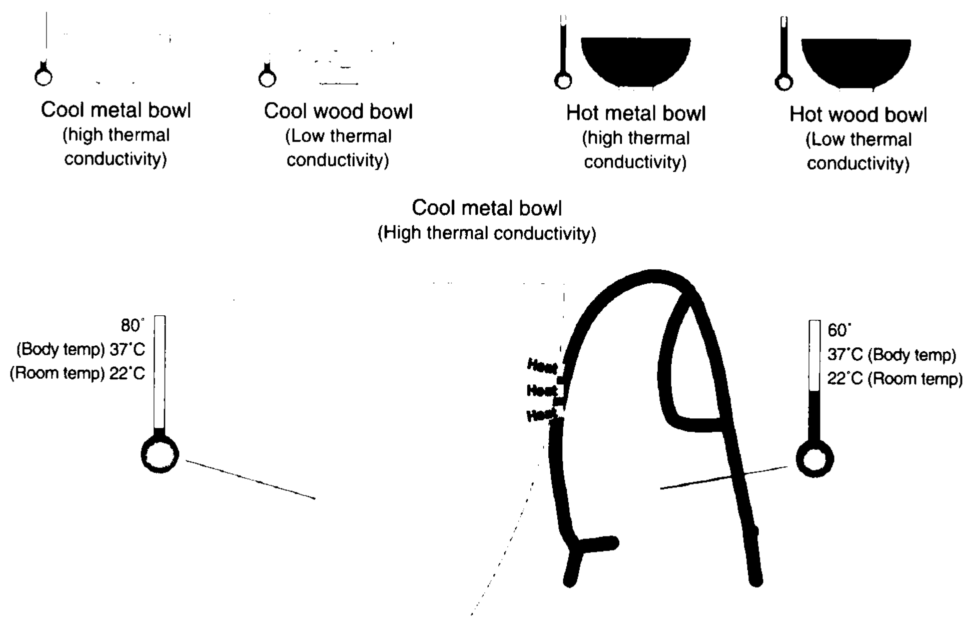
Alternatively, when students engage in argumentation as they participate in the PSDs, they have an opportunity to develop a more accurate view of the nature of science (Newton, Driver, and Osborne 1999). Students discover that disagreements about data interpretation often occur when people hold different assumptions and expectations prior to engaging in investigation into the same phenomenon. Such disagreements can help students understand that scientists' beliefs, theoretical commitments, training, and expectations affect the problems that the scientists investigate, how they conduct their investigations, and how they interpret their observations (Lederman and Lederman 2004). Students can also gain a better understanding of the social construction of scientific knowledge through this process. Students learn that success and confidence in one's conclusions depends on sharing and critiquing methods, data, and interpretations. Although often ignored in the classroom, these aspects of science are especially important to the development of a scientifically literate population because many political and moral dilemmas posed by contemporary science require an understanding not only of the content but also of the processes and practices of science (Duschl and Osborne 2002).

This type of activity is also designed to promote learning by taking advantage of the variation in student ideas and helping groups negotiate criteria for valid inferences (Linn, Bell, and Hsi 1998). For example, Linn (2005) suggests that students often have a repertoire of ideas about a given phenomenon that includes "ideas that are sound, contradictory, confused, idiosyncratic, arbitrary, and based on flimsy evidence" and that "most students lack criteria for distinguishing between these ideas" (p. 8). Similarly, Kuhn and Reiser (2006) suggest that students tend to rely on inappropriate criteria, such as the plausibility or the teacher's authority, in order to determine which ideas to accept or reject during discussions and debates. Engaging students in PSDs can provide an opportunity for students to learn how to distinguish between ideas using appropriate criteria.

FIGURE 3

During the *Thermodynamics: Probing Your Surroundings* project, students gather data and work with simulations before creating a principle to explain their ideas and participating in the online PSDs.





Finally, the PSD also makes it easier for science teachers to encourage students to participate in activities that require students to propose, justify, evaluate, and refine ideas. A great deal of research indicates that more traditional classroom environments and activities prevent productive argumentation. Even when students work collaboratively in small groups during laboratory-based activities, for example, these opportunities are rarely organized in a way that encourages significant discussion of the science involved. Instead, students' discussions tend to focus on the procedural aspects of the work (Alexopoulou and Driver 1996; Driver, Newton, and Osborne 2000) or the students attempt to complete the task individually rather than collaboratively (Cohen 1994). Furthermore, studies suggest that female students in traditional settings often contribute to the discussion less than male students, and students often feel social pressure to take on the views of their peers (Hsi and Hoadley 1997). Our research suggests that PSDs incorporate the voice of all students, expose students to new ideas, and create a need for students to evaluate the legitimacy of alternative viewpoints.

Future directions

We are now looking for teachers who are interested in using this online project and the PSD tool with students in their classrooms. We are particularly interested in

- examining how we can continue to improve this type of instructional technology in order to help students in grades 6–12 develop a more authentic understanding of the nature of science and develop the skills necessary to participate in argument-driven inquiry;
- designing professional development opportunities for teachers so that they can take full advantage of these technological tools; and
- recruiting collaborators in research, curriculum innovation, and professional development efforts in order to continue to improve online inquiry environments.

Classroom teachers who are interested in using this resource in their classroom or who would like to participate in our research are encouraged to contact the authors. ■

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