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# Pedagogy for the Connected Science Classroom: Computer Supported Collaborative Science and the Next Generation Science Standards

Brian J. Foley & John M. Reveles
California State University Northridge

**Abstract**

The prevalence of computers in the classroom is compelling teachers to develop new instructional skills. This paper provides a theoretical perspective on an innovative pedagogical approach to science teaching that takes advantage of technology to create a connected classroom. In the connected classroom, students collaborate and share ideas in multiple ways producing a record of work that is persistent and accessible via networked-based computing (i.e., "the cloud"). The instruction method, called Computer Supported Collaborative Science (CSCS), uses web-based resources to engage all learners in the collection, analysis, and collaborative interpretation of classroom data that turns hands-on classroom activities into authentic scientific experiences. This paper describes CSCS and how it corresponds to key parts of the Next Generation Science Standards.

The Next Generation Science Standards (NGSS) and the Common Core State Standards (CCSS) present an important moment in science education in this country. The new standards have the potential to significantly improve instruction. By integrating scientific practices with content, the NGSS will focus instruction on helping students apply scientific knowledge as opposed to memorizing discrete facts (National Research Council [NRC], 2012).

The NGSS will help teachers move away from such teaching by emphasizing student development of explanatory models that show their reasoning for the explanations and require them to use evidence to justify their ideas (Krajcik, Codere, Dahsah, Bayer, & Mun, 2014). Teachers will need to develop new methods to help students meet the new standards (Osborne, 2014). At the same time education is seeing a dramatic increase in the availability of computers or tablets in the classroom that enables new tools and techniques for teaching (Kearney, Burden, & Rai, 2015).

The success of the technology also depends on the ability of teachers to adapt increased technology use into their instruction. The new standards and increased technology is pressuring teachers to make changes to their instruction (Collins & Halverson, 2009). Teachers need support to successfully negotiate these transitions. This paper looks at one method to teacher support, particularly a pedagogical approach rooted in a set of instructional principles that help teachers take advantage of technology to prepare students for the NGSS.

In tandem with the nationwide adoption of new standards, many states are seeing a long-overdue move to equip students with computers to acquire 21st-century job skills. Recently, the Los Angeles Unified School District announced a plan to provide tablets to all of its 600,000 students (Blume, 2013). While many suburban schools have already made similar investments, the presence of technology resources in urban schools creates an opportunity to reduce the gaps in education and provide modern education experiences for underserved urban populations. The key to taking advantage of this transitional moment in time is to identify teaching methods that address the requirements of NGSS while meeting the needs of urban students.

With these issues in mind, a group of scientists, science education researchers, and science educators have been collaborating with teachers to develop a new kind of science instruction called Computer Supported Collaborative Science (CSCS). Building on the computer supported collaborative learning literature (Bereiter & Scardamalia, 2010; Hug, Kracjik, & Marx, 2005; Linn, Davis, & Bell, 2004; Scardamalia & Bereiter 2003; Suthers, 2006), CSCS is a pedagogical approach that takes advantage of cloud computing tools to create what the authors call the Connected Classroom.

The purpose of this paper is threefold: (a) it provides a theoretical basis for a CSCS pedagogical approach, (b) it articulates five key principles of instruction that CSCS pedagogy utilizes to address the NGSS in today's connected classrooms, and (c) it describes how CSCS instruction creates new opportunities for student collaboration in science using eight Science and Engineering Practices identified by the NGSS as a structure. The paper is largely theoretical, although it uses examples from our research over the past several years to illustrate the principles.

## Theoretical Framework

CSCS is a pedagogical approach that enables science teachers to take advantage of the connected classroom to create a student-centered learning environment (Herr, Rivas, Foley, Vandergon, & Simila, 2011). Early research with projects such as the Knowledge Integration Environment (Linn et al., 2004), WISE (Web-based inquiry science environment; Slotta & Linn, 2009) and the Center for Learning Technologies in Urban Schools (Hug et al., 2005) demonstrated that technology could be used to support science learning even in high-need urban classrooms. This notion is important since classrooms across the nation are rapidly acquiring increased access to technology and infrastructure needed to optimize 21st-century science teaching and learning practices.

A significant line of research examines the development of computer supported collaborative learning, (CSCL) techniques (Koschmann, Hall & Miyake, 2002; Scardamalia & Bereiter 2003; Suthers, 2006). CSCL research examines combinations of technology and social interactions that create powerful learning experiences for students, which includes using cloud-based technology to have students create shared documents and resources. Making the product of students' work public and subject to questioning and critique can foster a culture of knowledge building (Scardamalia & Bereiter, 2003). This type of student-centered activity allows them to engage in authentic classroom learning experiences that make them stakeholders in their own learning (Chinn & Malhotra, 2002).

A number of tools and methods have emerged to support CSCL, including discussion boards, collaborative writing (wikis), virtual jigsaws, and online learning spaces (Jeong & Hmelo-Silver, 2010). Research indicates that CSCL instruction can result in better conceptual understanding and greater metacognitive skills and knowledge (Scardamalia & Bereiter, 2006). When students are stakeholders and cocreators of their own conceptual knowledge in real time, they tend to learn content on a deeper level of understanding that is more meaningful to their lived experiences (Scardamalia & Bereiter 2003; Suthers, 2006).

While CSCL has been advocated for many years, relatively few teachers utilize these techniques (Porcaro, 2011), in large part due to the lack of technology and infrastructure to support its use in classrooms and a lack of teacher preparation and training (Roschelle et al., 2011). This situation, however, is rapidly improving to encompass classrooms that are becoming more connected. For instance, schools have begun to abandon desktop-based computer labs in favor of mobile carts of laptops and class sets of tablets (Mang & Wardley, 2012). Several districts have adopted one-to-one computing approaches (Warschauer, 2004; Warschauer, Zheng, Niiya, Cotton, & Farkas, 2014).

The CCSS have accelerated this process by encouraging states to do online testing using adaptive testing technology (Porter, McMaken, Hwang, & Yang, 2011). The next 5 to 10 years will likely see regular computer use become routine in the classroom. Although computers in the classroom can be utilized in many ways, the CSCL approach encourages the type of student-centered instruction that has been long advocated for instruction (Bransford, Brown, & Cocking, 1999).

Increases in computers in the classroom will create a challenge for schools and districts that now need to train teachers to use technology effectively for instruction. Studies of the adoption of technology tools suggest that teachers face many challenges (Janssen & Bodemer, 2013; Koptcha, 2012; Urhahne, Schanze, Bell, Mansfield, & Holmes, 2010).

Teachers' tend to adapt new tools and approaches to their situation and, thus, need resources that are flexible and adaptable with clear principles for use in the classroom (Kim, Hannifin, & Bryan, 2007; Songer, Lee, & McDonald, 2003). In other words, the technology and tools that work best for teachers are those that work seamlessly with their existent teaching practices and do not add an extra layer of responsibility to their already demanding teaching requirements.

CSCS is a pedagogical approach to help science teachers adopt CSCL techniques into urban science classrooms (Herr et al., 2011). CSCS pedagogy builds on a foundation of science education research on the importance of students taking a lead role in science inquiry and making sense of data (Songer & Gotwals, 2012; Songer et al., 2003). CSCL research shows that when students are given opportunities to collaborate on scientific problem solving, they understand the conceptual ideas and scientific processes in more meaningful ways than they do from traditional science teaching (Koschmann et al., 2002; Scardamalia & Bereiter 2003, 2006; Suthers, 2006). Classrooms have the potential to become knowledge-creating organizations in their own right.

Bereiter and Scardamalia (2010), distinguished between *productive knowledge*—knowledge that is of significant use in the acquisition and creation of further knowledge and *knowledge building*—producing and improving theories as especially dynamic types of knowledge creation that can be lived, tinkered with, and explored through trial and error. The role of the teacher also changes when CSCL is used. Meier, Spada, and Rummel (2007) described the teacher as orchestrating the class rather than instructing students.

Science practices have taken on increased importance with the adoption of the NGSS. In the NGSS students are expected to make sense of data, use models, and construct scientific explanations in ways that are more akin to the ways that practicing scientists "do science" (Herman, 2009; NRC, 2012). This shift in emphasis in students' science learning means that students will need to engage actively in the practices involved in doing science while they are learning the scientific concepts involved as they explore and investigate phenomena.

Connected learning environments provide teachers with myriad opportunities to utilize new cloud-based document technologies to teach science content while engaging students in these science and engineering practices. The CSCS instructional model utilizes a collection of technology teaching tools with clear instructional principals to address the NGSS goals (Herr et al., 2011). CSCS engages learners in the use of interactive, collaborative cloud-based technologies to collect and analyze large sets of data readily from multiple lab groups and class sections so they can focus more attention on the analysis and interpretation of data, as required by the NGSS (Herr & Rivas, 2010; Herr et al., 2011).

## Developing the Pedagogy for the Connected Classroom

A connected classroom is one in which computers or tablets connected via the Internet are accessible to all students (one to one or one to group). The requirement is a relatively simple. According to a recent Public Broadcasting System (2013) survey, classroom use of technology is becoming increasingly common in schools. Using computers or tablets and the Internet allows students and teachers to share information instantly and enables computer supported collaborative learning.

CSCL provides general approaches to enhance learning. To adapt CSCL to urban science classrooms, researchers worked with classroom teachers on planning and observed science instruction using CSCL technology. The release of Google Apps in 2007 (Bodis, 2007) provided a flexible and accessible set of CSCL tools for the classroom. The researchers began to work with Google tools in university classrooms and then with teachers in K12 classes (Herr & Rivas, 2010). Convinced of the value of the technology tools, the research team gradually developed practices that support student learning as they gain more experience and the technology to do so.

The researchers developed training materials for both preservice and in-service science teachers during work with in-service teachers in summer workshops (available at csunscience.com). Beyond training, the researchers observed classroom teachers to see how they were able to utilize technology and what aspects were problematic. Building off the fundamental precepts espoused by CSCL, five instructional principles were identified as factors key to collaborative science instruction in a connected classroom. These principles are accessible to urban teachers and enable them to transform traditional instruction into the orchestration of student collaboration.

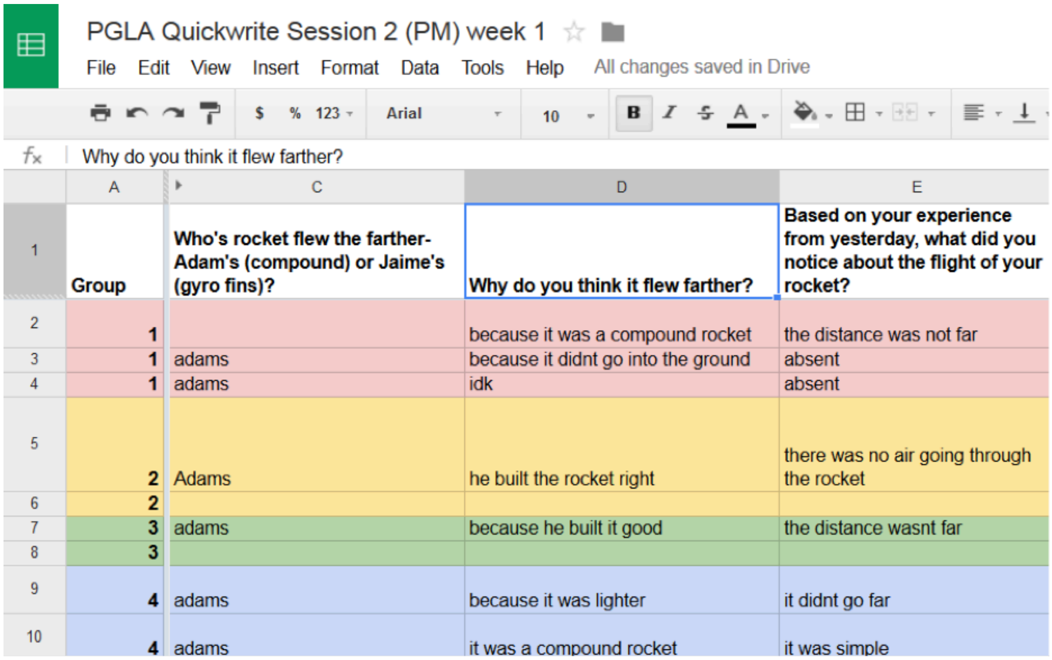
The features of the Google suite of tools provided inspiration for many of the principles but partially constrained them as well. Google provides a suite of integrated resources that provide multiple means of collaboration (Nevin, 2009), which is different from a fully integrated tool like the WISE website (Slotta & Linn, 2009). An integrated tool can control the student interaction by forcing a sequence or customize collaboration and provide feedback on different behaviors (Linn et al., 2004). Google tools, on the other hand, rely on peers and the teacher to provide the feedback and on students to follow instructions or develop their own sequences.

The suite of tools includes Google Sites, an easy way for teachers to create and maintain websites; Google Documents, a word processing tool that allows simultaneous editing by multiple people; and Google Spreadsheets, a spreadsheet with simultaneous editing. These three tools form the basis of the CSCS instruction. Some teachers also incorporate Google Presentations (similar to PowerPoint) and Google Drawing tools that enable many people to collaborate on the same document at the same time. Google Moderator provides a way for teachers to have students vote on each other’s ideas or writing. Beyond Google, the research team has worked with teachers to incorporate other resources from the web (e.g., online simulations) or the classroom (e.g., smartphones and digital cameras).

The key advantage of the Google tools is the ability to share documents so multiple students can access the same document at the same time. This capability allows for instant sharing of ideas as well as creating a record of contributions so students and teachers can refer to previous ideas as they move forward. One technique that the researchers found particularly useful was to have all students (or each group) join a spreadsheet at the same time and assign each student a row. The teacher can pose a question (in the top row) and then student each reply in their row.

The research team called this instant questioning of the class a *quickwrite* (Figure 1). A quickwrite can be a valuable tool for getting student's initial ideas on a topic or for checking to see if students are ready for a test. The ability to poll students during class works similarly to student response systems (SRS), which can create a more interactive class discussion and lead to valuable learning experiences (Wienman, Perkins, & Gilbert, 2010).

The researchers recognized early on that these tools had great potential for instruction but would require teachers to develop new skills and new approaches to teaching (Rivas & Herr, 2010). Our research focuses on how to help teachers understand the technology and pedagogy that can transform their instruction (d'Alessio & Lundquist, 2013; Foley, Castillo, & Kelly, 2013; Herr & Rivas, 2010; Herr et al., 2011). The keys to helping teachers adopt CSCS is to summarize the key principals of instruction and provide clinical teaching experiences that help teachers develop confidence in their ability to use CSCS in the classroom (Foley et al., 2013). Teachers are often hampered by limited technology available in urban classrooms and by feeling the need to use direct instruction to meet standards. The current climate suggests that both of these obstacles are decreasing. Schools are beginning to invest in technology, and the NGSS emphasize the importance of scientific practices. This paper describes how CSCS instruction, while not developed for NGSS, helps teachers address the standards and expectations in the NGSS.



PGLA Quickwrite Session 2 (PM) week 1

File Edit View Insert Format Data Tools Help All changes saved in Drive

fx Why do you think it flew farther?

| | A | C | D | E |
|---|---|---|---|---|
| 1 | Group | Who's rocket flew the farther- Adam's (compound) or Jaime's (gyro fins)? | Why do you think it flew farther? | Based on your experience from yesterday, what did you notice about the flight of your rocket? |
| 2 | 1 | | because it was a compound rocket | the distance was not far |
| 3 | 1 | adams | because it didnt go into the ground | absent |
| 4 | 1 | adams | idk | absent |
| 5 | 2 | Adams | he built the rocket right | there was no air going through the rocket |
| 6 | 2 | | | |
| 7 | 3 | adams | because he built it good | the distance wasnt far |
| 8 | 3 | | | |
| 9 | 4 | adams | because it was lighter | it didnt go far |
| 10 | 4 | adams | it was a compound rocket | it was simple |

**Figure 1.** *Screenshot of a quickwrite from a CSCS class.*

## Describing CSCS Through Five Principles of Instruction

The CSCS model of instruction is based on two related theories about science education:

1. A knowledge-centered, learner-centered classroom allows students to construct better understanding of science concepts and the nature of science (Meier et al., 2007; NRC, 2012).
2. Collaborative technology tools can transform science classrooms to be knowledge-and-learner-centered (Foley et al., 2013; Herr & Rivas, 2010).

The five CSCS principles described in the following paragraphs are designed to help teachers utilize the connected classroom to transition from traditional teacher-centered instruction toward the orchestration of effective collaborative learner-centered science instruction. The CSCS principles are not meant as a comprehensive definition of good science teaching. They articulate key instructional techniques that support collaborative science. It is also important that the principles not burden teachers with additional responsibilities. They are designed as a guide for teachers to draw upon as they develop their own understanding and skills regarding the use of classroom technology to teach science.

**1. Information is shared with the class online.** Teachers and students share information online for the entire class to see. Teachers share class information, lecture notes, links to activities, and rubrics, while students' work (from brainstorming and data from experiments to polished assignments) can all be posted online. Teachers and students can have a shared understanding of what happened in the science lesson or activity and what is happening next. While some students' grades and feedback should be kept private to protect students, more-general feedback can be made public. This type of classroom sharing enhances the quality of student work by allowing them to see one another's work within the context of the science lessons, investigations, and activities and promotes a more cohesive classroom scientific community (Bereiter & Scardamalia, 2010).

**2. Teachers check on students' understanding often.** Teachers use online polling, quickwrites, and observations of students' work in progress for formative assessment. Utilizing this practice, teachers can collect large student data sets across groups or classes and analyze them quickly and accurately. This type of formative assessment impacts all students rather than only the handful of students who raise their hands during more traditional assessment approaches. As instructors analyze student data, they have an opportunity to adjust their instruction to meet student needs. Formative assessment carried out in this manner helps teachers know which students are struggling and when the entire class needs to slow down or speed up (Herr & Rivas, 2014).

**3. Data from experiments and simulations is pooled.** Students pool research data in collaborative spreadsheets or other tools so they can see trends that are often not visible to individuals or small student groups and learn to identify outliers. Pooled data allows students to spot outliers and correct errors instantly rather than turning in flawed results (d'Alessio & Lundquist, 2013). Collaborative spreadsheets allow for easy pooling even while students are still working with their group data. Furthermore, pooling data across classes or schools allows them to see data in context and helps students compare analyses across larger data sets.

**4. Data analysis is emphasized.** Teachers place an increased emphasis on the analysis of student-collected data. Many science teachers focus on the hands-on part of labs and shortchange the data analysis (Singer, Hilton, & Schwiengruber, 2005). They often have limited time in which to conduct science instruction, and they wind up running out of time to focus instruction on data analysis. Online data and analysis tools dramatically reduce the time necessary to collect investigation data and make the analysis easier and more conceptual rather than procedural (d'Alessio & Lundquist, 2013). Pooled data enables students to compare their analysis individually to others as well as collectively across investigations and data sets. With digital tools students can easily produce graphs and explore trends in the data as a community of science learners, thereby increasing their interest and learning.

**5. Students' explanations are shared and compared.** Teachers make explanations a central part of science instruction where students are engaged in creating and critiquing explanations (Songer & Gotwals, 2012). They can be in written or spoken format, through drawings, or through animations so long as they are recorded for easy archival and sharing. Authentic science practice needs to include the community discussion of scientific explanations for the purpose of developing consensus. Scientific discourse is crucial to student learning and helping students understand the nature of science knowledge (Kelly, 2007). Collaboration tools allow students to share their explanations and get feedback on their ideas and writing. Shared conclusions allow for further discussion and the consensus building that is essential for inquiry (Berland & Reiser, 2009). Tools like Google Moderator allow students to think about the quality of different explanations and come to consensus as to the best one (d'Alessio, 2014).

The Five Principles of CSCS Instruction provide a set of pedagogical practices that enable students and teachers to participate in collaborative inquiry-based science. This type of science teaching and learning allows students to engage authentically in the content being investigated in ways that are aligned with 21st-century skills. While not exhaustive, these science teaching principles describe key ways to use collaborative technology to scaffold and engage students in scientific inquiry. In doing so, teachers and students can work together to reach consensus about best scientific practices as a community.

## NGSS Science in a Connected Classroom

The NGSS called for instruction that helps students learn and appreciate the practices of scientists and engineers. Appendix F of the NGSS identified eight key practices that should be part of science curricula, which are listed in the following paragraphs. The NGSS practices are used to provide examples of how CSCS pedagogy supports the type of instruction the new standards call for. The CSCS pedagogical approach draws upon collaborative teaching tools for engaging students in the scientific and engineering practices that are linked to the NGSS by facilitating student development of such practices. Many of the anecdotes shared here are taken from middle and high school science teachers who have attended CSCS training and implemented CSCS techniques into their classes. Examples and resources for teachers are available on our website CSUNscience.com.

**1. Asking questions (for science) and defining problems (for engineering).** Teachers can use a quickwrite to have students submit research or design questions on a topic they are studying. This activity is similar to the commonly used technique of writing questions into a notebook. The collaborative documents, however, allow the class to go beyond the initial question writing. As students are able to see each others' questions, they gain more ideas about the nature and quality of their own questions and can refine their thinking on the inquiry topic as they refine their research questions. One of the most challenging parts of doing science inquiry is having students ask authentic questions when teachers often have a specific study in mind (Chin & Osborne, 2010). Ideally, students would take ownership of the research, but teachers often need to be able to prepare experiments ahead of time. One approach is to have students create their own questions but then come to a consensus as a class (Hand, 1999). Collaborative documents allow students to submit ideas and questions to the group, so they can compare and pick only research questions that are practical and authentic.

**2. Developing and using models.** Scientific models can be accessed in many ways, through writing, images, and concept maps. Student drawing can provide a way for students to articulate their own ideas (van Joolingen, Bollen, Leenaars, & Gijlers, 2012). Online documents allow students to articulate models via writing, drawing, and diagramming. Because documents are stored in the cloud, students can link models to the data collected from experiments to see how well their models match.

In one activity a teacher had students do drawings (using Google Drawing) to illustrate what they thought might be in the "Mystery Bottle" (Figure 2). They changed their drawings after conducting tests on the bottle. The evolution of their drawings was stored in the document's revision history. The teacher linked each group's drawing to the class website so they could compare ideas and plan further tests. The class set of models allowed for discussion either online or in the classroom, engaging students in the comparison and refinement of the models and the modeling process itself.

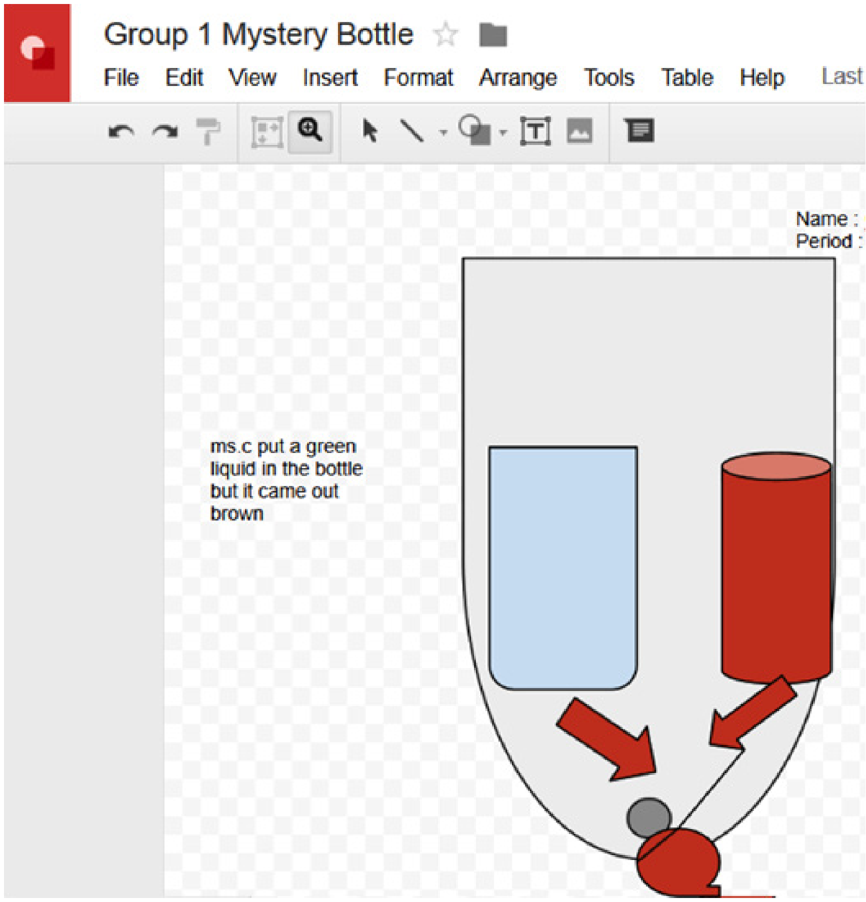



**Figure 2.** *Drawing from students doing the Mystery Bottle activity (using Google Drawing). The teacher poured green liquid in, but a brown liquid came out the bottom. Students communicated proposed theories about what was inside the bottle by drawing. This group imagined two containers inside the large bottle.*

**3. Planning and carrying out investigations.** Online documents can be created and shared with the class almost instantaneously, eliminating the need to print worksheets in advance with predefined research methods. Teachers can discuss methods with students, develop a consensus methodology, and create a document in the moment that matches the plan. Documents created in class can be instantly shared and then serve to scaffold students as they conduct their investigation.

Alternatively, students can use collaborative documents to get feedback from peers or the teacher. One teacher has students each create and share a document for their science fair projects. Then the teacher can observe students' progress and provide feedback by adding comments to the document on their research questions and research over time. Students never loose time by having to turn in their work. It is always available to both the students and the teacher.

**4. Analyzing and interpreting data**. Data entered online can be easily shared or pooled to help scaffold the analysis. Spreadsheets are an excellent tool for pooling data using Google Forms or entering data directly to the spreadsheet. When data are pooled, students can more easily see trends and spot errors in the data and can identify problems before they turn in their reports (Figure 3). Graphs or scatterplots allow students to explore data in different ways and create images to illustrate their findings (d'Alessio & Lundquist, 2013). One teacher wrote,

Data pooling is good because students can spot outliers, mistakes like using the wrong unit of measure or putting a decimal in the wrong place, and then make corrections or redo their investigation if time permits. This is good practice for thinking about data and analyzing it.

These tools help focus classes on data analysis rather than data collection.

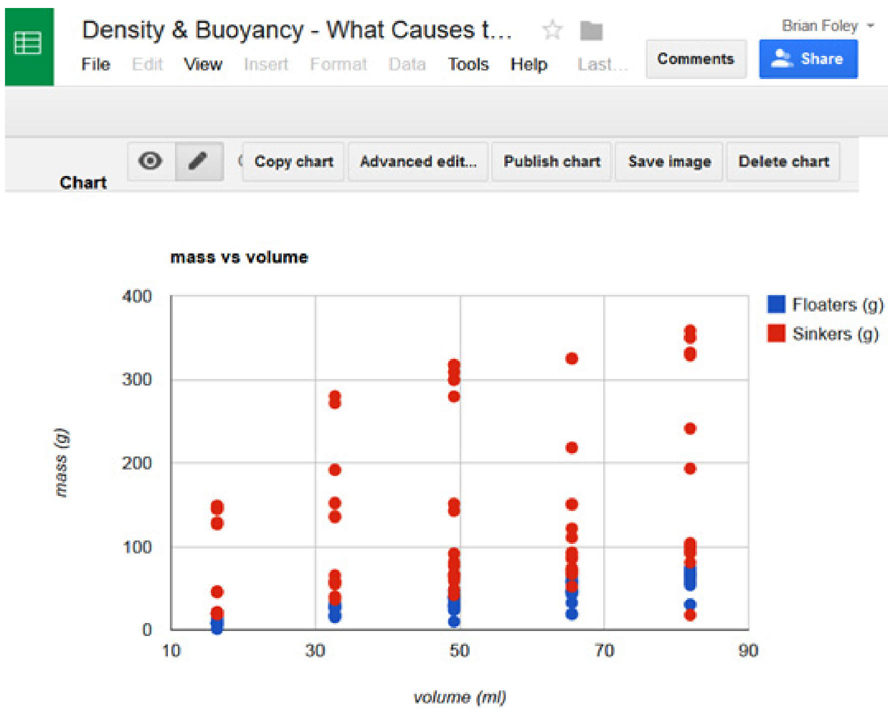



**Figure 3.** *Graph from a lab using density cubes. Students combine cubes of different materials and see if they float or sink. They enter their data (and the results) into a spreadsheet. The teacher sets up this scatter plot. The pattern and the outliers are clearly visible.*

**5. Using mathematics and computational thinking.** Spreadsheets allow students to use mathematics and computation to make sense of their data. Students can create formulas to convert data and do simple calculations (e.g., density). Taking full advantage of spreadsheets to engage students in the use of mathematics and computational thinking empowers teachers and students by allowing them to see the direct results of their own and each other's data analysis. This type of student science engagement moves students away from traditional formulaic science experiences with prescribed outcomes to more-authentic, inquiry-based science activities and lessons that allow students to analyze their own collected data sets mathematically.

**6. Constructing explanations (for science) and designing solutions (for engineering).** Students' written results bring together data and analysis (including visualizations) and are easily shared and compared to help the class reach consensus. When the students work from pooled data their conclusions are easier to compare. Tools like quickwrites (Figure 1) and Google Moderator (Figure 4) provide ways for students to share their ideas. This process helps develop scientific literacy and can support language learners by providing models and instant feedback on their work. One study found that classes using Google Moderator to compare student explanations had higher levels of science understanding (Reynolds, 2013). Over time students began to compete to see whose explanation would be the highest rated—focusing on the completeness of explanations and writing.

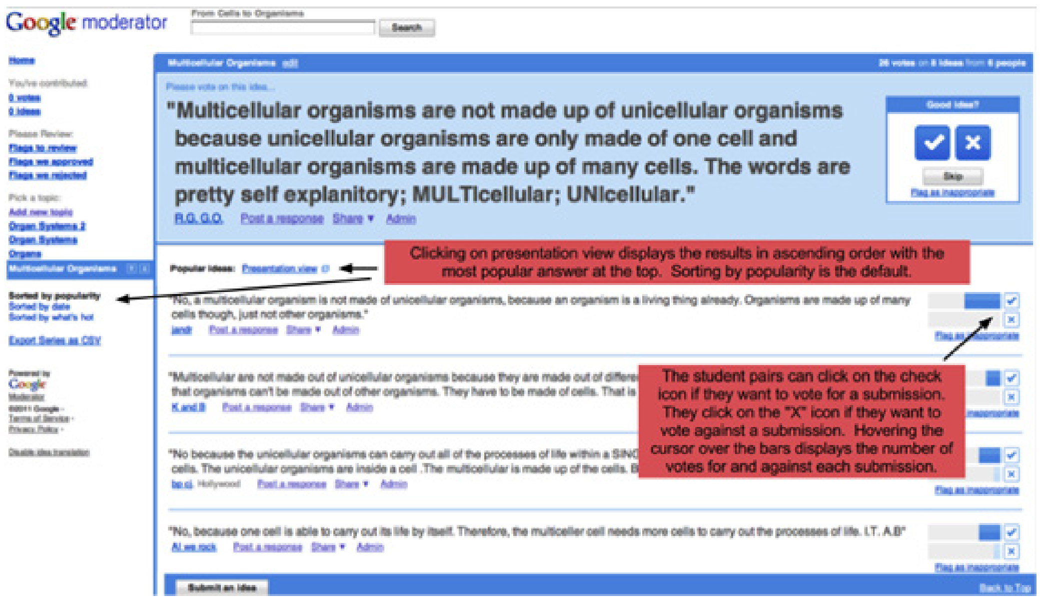



**Figure 4.** *Screenshot from Google Moderator where students have entered their answer to the question, "Are multicellular organisms made up of unicellular organisms?" Students voted on each response, and the ones with the most votes moved to the top of the list (Reynolds, 2013).*

**7. Engaging in argument from evidence**. When a teacher creates a website with a daily agenda and links to resources and student work (in shared documents), a record of the class work is created that can be easily accessed and referenced. Because all work is stored in the cloud, students' contributions are persistent. Previous work can be linked to show support for an argument or linked to counter it. This encourages continuity and accountability in explanations and argument. Data is never more than a few mouse clicks away. Not only does this science and engineering practice enable continuity and accountability for student-generated work, it also creates a scientific community of practice within the classroom that engages in a scientific debate and argument in ways that are more similar to the ways of practicing scientists.

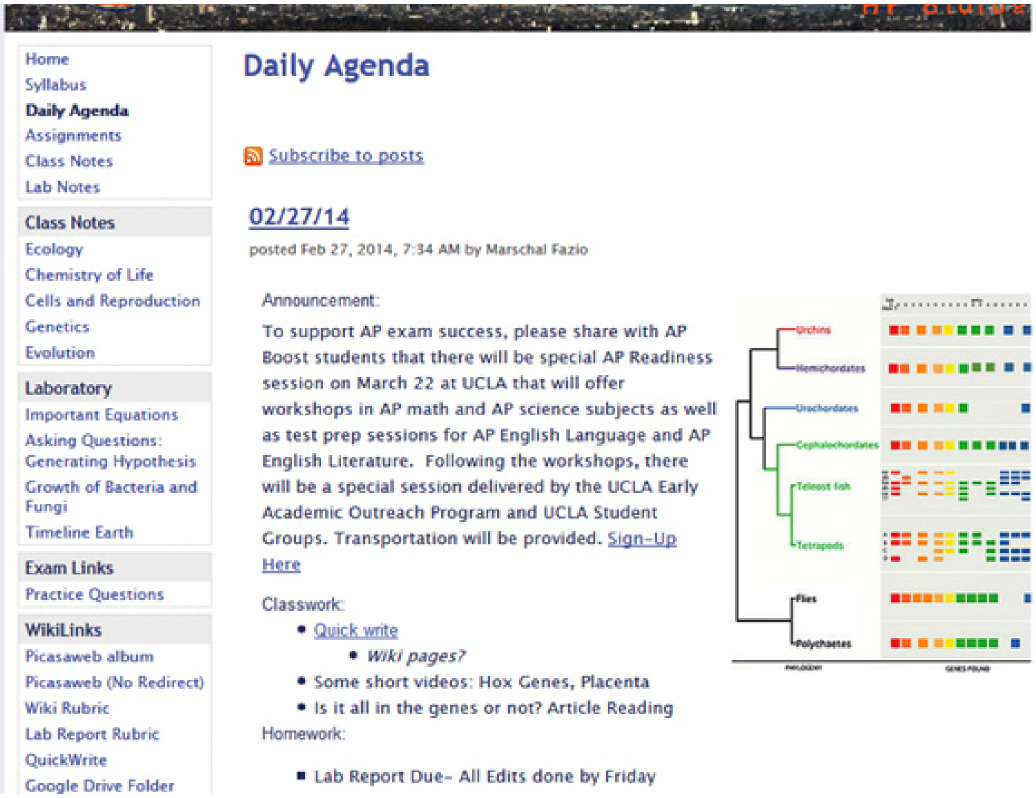



**Figure 5.** *Screenshot from a teacher's website where students posted their daily agenda with links to quickwrites and wiki pages and class notes. This record makes it possible to use evidence to support arguments and makes students accountable for their work all semester.*

**8. Obtaining, evaluating, and communicating information.** Because much of the student's work is shared publicly with the class, the stakes for classwork become higher (Scardamalia & Bereiter, 2006). Students think more about all their work as a form of communication. Shared ideas through spreadsheets and Moderator (Figure 4) can be evaluated by peers as well as the teacher. In a connected classroom students are communicating ideas all the time. Once students have finished their work many ways exist to use online tools to communicate their conclusions. Students often use tools like Google Presentation to share their work (Figure 6). Other students like to go outside of the Google tools for sites like GoAnimate (goanimate.com) and Scratch (scratch.mit.edu) for media to help communicate ideas. These site are easily shared by linking from the class website.

## Significance

The NGSS provide an opportunity to make significant changes in the ways science is taught at all levels of K-12 instruction, including bringing instructional methods into the 21st century. This shift in teaching science proposed by the NGSS will also require a paradigm shift in the ways teachers engage their students in science and engineering practices. Teachers can capitalize upon this shift in new standards-based teaching requirements by utilizing technology to enhance their existent science teaching practices.

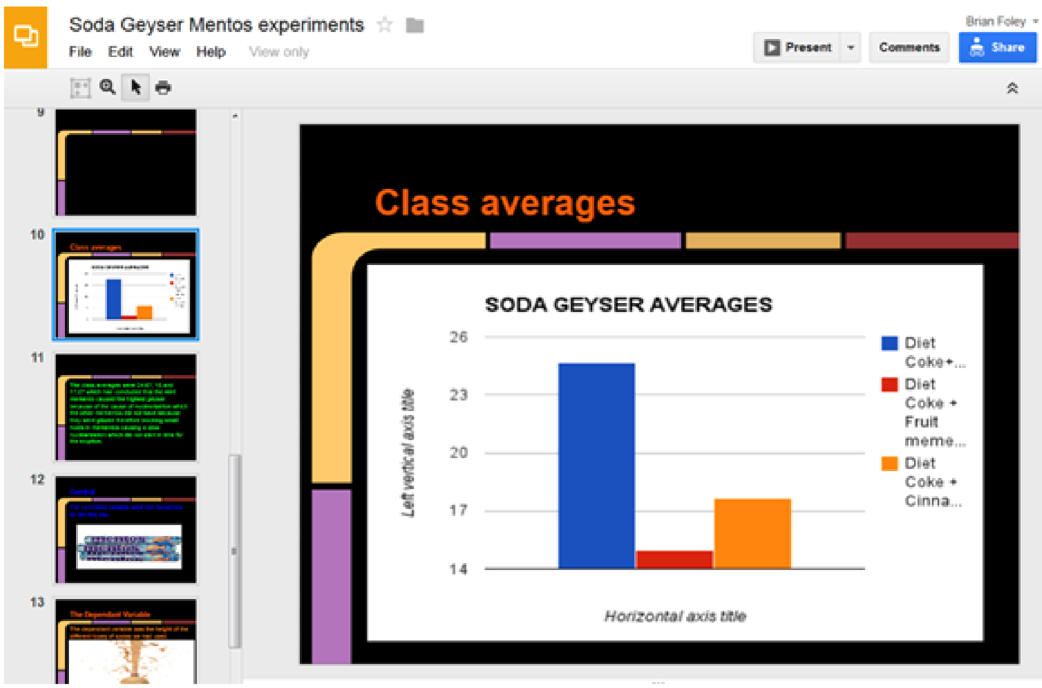



**Figure 6.** *Screenshot from Google Presentation, where students presented the results of their research (i.e., which combinations of mentos and soda made the biggest geysers).*

The timing of the development of CSCS is in line with the changing science education landscape and provides a pedagogical approach that encourages learning science content and practices through collaboration. At this point, schools are increasingly adopting one-to-one computing, where students are each assigned a laptop, iPad, or some other form of technology that allows them access to the Internet. Such increased equitable access to technology allows teachers to draw on electronic tools and resources to engage students in learning science by adopting CSCS instructional techniques. CSCS instruction can help teachers engage students in authentic inquiry in science that addresses the NGSS without adding additional curricular demands.

Last, CSCS provides a pedagogical model that engages students in authentic scientific inquiry by creating a culture of collaboration in today's connected classrooms. Significantly, this type of science engagement moves students away from traditional science lessons with prescribed outcomes to more authentic forms of scientific inquiry that allows students to learn important science and engineering practices.

### CSCS Pedagogy Supports the NGSS and CCSS

CSCS uses the tools available in the connected classroom to engage all learners in the collection, analysis, and interpretation of individual data in the context of whole-class data. Both the NGSS and the CCSS, through the science literacy standards, place substantially more emphasis on scientific practices than exist in the current state standards.

Under the new standards, students are expected to be able to support scientific claims with logical reasoning and relevant, accurate data and evidence verbally and in writing. Many teachers are not yet ready for this shift. Less-experienced teachers tend to rely on didactic techniques, such as reading textbooks and having students answer questions at the end of the chapter, rather than on experiential learning or inquiry-based instruction that promotes higher order thinking skills (e.g., Newton, 2001). Both in-service and preservice teachers must develop new teaching skills to meet the demands of NGSS. By articulating the five CSCS principles that we have found useful for science teachers, we provide a new pedagogy that promotes the use of these new tools to meet the demands of the NGSS.

### CSCS Pedagogy Accessibility to Teachers' Existent Science Teaching Practices

The timing of CSCS with efforts to bring technology and supporting infrastructure into the classroom helps make use of new technology and tools available for teachers to utilize with their science teaching practices. At the same time, schools are increasingly adopting one-to-one computing in the science classroom. As more schools invest in technology for classroom use, teachers need to learn how to take full advantage of these tools. Instead of merely creating PowerPoint slides, watching videos, or reading websites, with CSCS pedagogy students engage in hands-on science, data pooling, analysis, and interpretation. New layers of responsibility need not be added to teachers' already-demanding teaching practice. Teacher can adapt CSCS to the existing technology infrastructure in their classrooms.

### Aligning Authentic Scientific Inquiry With the NGSS Science and Engineering Practices

Over 25 states have participated in the development of the NGSS, and to date, 11 have adopted the standards. Even states that have not adopted NGSS will likely be influenced by the shift toward science and engineering practices. The shift in the goals of science instruction in the NGSS will require a paradigm shift in the ways teachers engage their students in science and engineering practices. CSCS instruction supports the teaching practices identified in the NGSS and turns hands-on classroom activities into more authentic scientific experiences.

CSCS provides teachers with techniques to help meet the demands of the NGSS through the use of collaborative authentic inquiry. This type of inquiry promotes the development of science literacy skills by engaging students in doing science in ways that are similar to the work of practicing scientists. If science teachers at all levels are to be expected to engage their students in the NGSS, they need tools to facilitate the engagement of authentic science learning. CSCS provides a pedagogical model that does so by creating a culture of collaboration in today's connected classrooms.

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Brian Foley
Secondary Education Department
CSUN
18111 Nordhoff
St. Los Angeles CA 91330-8265
Email: brian.foley@csun.edu