

**TITLE:** Engaging Students in the Science and Engineering Practices of the Next Generation Science Standards (NGSS) with Computer Supported Collaborative Science (CSCS)

**TOPIC:** Science Education

**PRESENTATION FORMAT:** Workshop

**DESCRIPTION:** Computer Supported Collaborative Science (CSCS) is a methodology that uses collaborative cloud-based resources to engage all learners in the collection, analysis, and interpretation of individual data in the context of whole-class data. CSCS turns hands-on classroom activities into more authentic scientific experiences -- shifting the focus from cookbook data collection to thoughtful data analysis required by the Next Generation Science Standards (NGSS).

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## **Engaging Students in the Science and Engineering Practices of the Next Generation Science Standards (NGSS) with Computer Supported Collaborative Science (CSCS)**

### **I. SUBJECT / PROBLEM**

In 2012, The National Research Council, representing the National Academies of Science, Engineering, and Medicine, published “*A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*” as the first step in a process to create national standards for K-12 science education. Through a collaborative, state-led process science standards are being developed that will be based on the *Framework*. It is anticipated that the vast majority of states will adopt the *Framework* and the standards, currently known as the *Next Generation Science Standards (NGSS)*.

The National Research Council states that “The overarching goal of our framework for K-12 science education is to ensure that by the end of 12th grade, all students have some appreciation of the beauty and wonder of science; possess sufficient knowledge of science and engineering to engage in public discussions on related issues; are careful consumers of scientific and technological information related to their everyday lives; are able to continue to learn about science outside school; and have the skills to enter careers of their choice, including (but not limited to) careers in science, engineering, and technology.” In addition, the NRC states that “Currently, K-12 science education in the United States fails to achieve these outcomes, in part because it is not organized systematically across multiple years of school, emphasizes discrete facts with a focus on breadth over depth, and does not provide students with engaging opportunities to experience how science is actually done. (NRC, 2012).

The *Framework* recommends that science education be built around three dimensions: (1) scientific and engineering practices, (2) cross cutting concepts that have common application across fields, and (3) core ideas in four disciplinary areas: physical sciences; life sciences; earth and space sciences; and engineering, technology, and applications of science. The *Framework* draws upon ideas set forth in earlier reform documents such as *Project 2061* (American Association for the Advancement of Science, 1993), and the *National Science Education Standards* (NRC, 1996) but is destined to be more influential

since most states have already adopted the *Common Core Standards* (National Governors Association, 2012) in mathematics and English and have expressed interest in adopting the *Next Generation Science Standards* as well. The *Framework* and *Next Generation Science Standards* will provide a roadmap for reforming science education and will create a need for new teaching strategies to traverse this map. Fortunately, recent advances in collaborative cloud-based computing have provided the technological tools which allow the implementation of new teaching methodologies by which many of these goals can be reached more effectively than previously possible.

## **II. DESIGN**

*Computer Supported Collaborative Science* (CSCS) is a teaching methodology that uses collaborative web-based resources to engage all learners in the collection, analysis, and interpretation of individual data in the context of whole-class data. CSCS fosters scientific inquiry by using collaborative online resources to assess prior knowledge, collect and analyze student ideas, data, and comments, and provides instructors the opportunity to perform continuous formative assessments to inform and reform their own instruction. CSCS turns hands-on classroom activities into more authentic scientific experiences -- shifting the focus from cookbook data collection to thoughtful data analysis.

The CSCS model engages all students in learning science and provides experience in how science is actually done. The CSCS model provides a pedagogical framework for science teachers seeking to implement the goals of *Framework*.

- **Prior Knowledge and Student Engagement.** Often, science lessons ignore prior knowledge and cultural influences, complicating the challenge of teaching in a diverse classroom (Brown, 2004). CSCS uses online surveys to assess students' initial understanding of new topics. This allows teachers to learn about preconceptions to be addressed and helps students to become aware of their naïve conceptions. Students remain engaged when they are regularly asked to commit responses to formative assessment. (Herr et.al, 2012)
- **Collecting large data sets.** In traditional classes, lab groups collect data independent from other lab teams. By combining data sets online, students recognize patterns that are only visible when students pool their data. Students compute averages, plot data together and gain firsthand experience for what it means for an experiment to be repeatable.
- **Focusing on interpretation.** In verification labs, experiments stop once data are collected because the results are known before they start. In CSCS, students post collaborative lab reports online linking to relevant data and graphs. Shared conclusions allow for further discussion and the consensus building that is essential for inquiry (Berland & Reiser, 2009). Automated graphing of data using CSCS tools can reduce the load on working memory, allowing for more cognitive resources to be devoted to data analysis (Hmelo-Silver, Duncan, & Chinn, 2007).

## **III. ANALYSIS & FINDINGS**

The following example from Mr. Arias' biology class illustrates how the CSCS model can transform an existing classroom laboratory activity into a student-centered collaborative learning experience. Students are exploring the function of enzymes by performing a classic hands-on lab using liver (which contains catalase) and hydrogen peroxide. The lab is conducted before enzymes are fully explained, providing an opportunity to explore the characteristics of enzymes.

On the first day, students begin by discussing in groups what they believe are the function of enzymes in the human body. They brainstorm variables they can explore in the chemical reaction (e.g. temperature, pH, volume, etc.). As teams, they use laptops to

post their suggestions using an online spreadsheet. Each student then ranks the suggestions using instant online survey. After consulting the survey results, each team chooses three variables to investigate and discusses the best procedure for making measurements, eventually posting their procedure to the class wiki. Mr. Arias asks students to make predictions about which variables they think are most likely to affect enzyme activity. Rather than calling on individual students to share their ideas in the class discussion, he makes them all commit their predictions to an online survey form. As teams conduct the experiment, they record data in an online spreadsheet side-by-side with other lab teams. Using cloud-computing tools like Google Docs, all teams can edit the file simultaneously from different computers throughout the room. The bell rings and students must leave.

Even though the activity itself has been interrupted, students return to their stored work the next day. Their predictions, procedures, and data are all well organized online and Mr. Arias begins the day's discussion by displaying class data using a web-based graphing tool. Immediately, students recognize that certain data points are outliers. Students turn to the team responsible for contributing the outliers and ask them to explain their protocol for collecting their data. The entire class speculates about causes for variations. They record their ideas in a threaded online discussion forum. Following the discussion, each lab team writes a lab report that explains their data, how it connects to the class data set, and generates conclusions about enzyme activity. Mr. Arias reminds students how scientific findings rely on finding patterns in data as he highlights how their contributions to the class spreadsheet have allowed them to evaluate a larger data set.

The third day's quiz (another online form) asks students questions about the function of enzymes taken from their collaborative online lab reports. Mr. Arias then explains how enzymes work and enhances his explanation with a few short video demonstrations of how certain variables such as temperature affect the breakdown of catabolites such as hydrogen peroxide. He directs students to an online simulation of catalase activity to see how different variables affect the reaction. Students are then asked to compare their current understanding of enzymes to what they initially thought on day 1 through an online form. Mr. Arias monitors student responses as they are submitted, formatively assessing student understanding so that he may plan his next steps to insure student understanding.

Note: Fifty middle and high school science teachers have participated in a two-week intensive CSCS workshop at California State University Northridge. These teachers will be implementing CSCS activities in Fall 2013. We have employed an external evaluator to investigate the effectiveness of the CSCS model in addressing Dimension 1 of the Next Generation Science Standards (NGSS) and plan to present our findings at the NARST meeting, if our paper is accepted.

#### **IV. CONTRIBUTION**

The CSCS model provides a mechanism for engaging students in the scientific and engineering practices that are common to all aspects of science, technology, engineering and mathematics (STEM) education, listed in *Dimension 1* of the *Framework for K-12 Science Education* (NRC, 2012):

**(1) Asking Questions and Defining Problems** – Secondary students struggle to develop researchable questions for inquiry activities or science fair projects. Fortunately, teachers can guide students through this process with much greater efficiency using the CSCS model. For example, a teacher can solicit research questions surrounding a particular phenomenon. Students enter their questions into a blog and simultaneously see the ideas of their classmates. The teacher then highlights specific questions and illustrates how they may be refined into researchable questions. Students are then asked to post suggestions for their peers. The teacher monitors all activity and further clarifies the process of formulating researchable questions and defining researchable problems. Students learn by seeing numerous examples edited and

refined in the collaborative environment of the blog.

**(2) Developing and using models** – A key difference between novice learners and expert learners is that “experts notice features and meaningful patterns of information that are not noticed by novices.” (Bransford et. Al., 1999). The NRC recognizes the significance of pattern recognition by placing it as the first *cross-cutting concept* in *Dimension 2* of the *Framework* (NRC, 2012). Novice learners become expert learners by modeling the metacognitive strategies of experts. Novice learners gain metacognitive skills as they watch teachers describe their use of pattern recognition in the development of models and hypotheses. Collaborative cloud-based documents allow students to see patterns in class data as well as patterns in the way their peers develop models.

**(3) Planning and carrying out investigations** – In *America’s Lab Report*, The National Research Council states that “Laboratory experiences provide opportunities for students to interact directly with the material world (or with data drawn from the material world), using the tools, data collection techniques, models, and theories of science.” (NRC, 2006b). According to the NRC, “The quality of current laboratory experiences is poor for most students.” The NRC concludes that one reason for poor laboratory experiences is insufficient time to plan and carry out investigations. The CSCS model makes planning and conducting investigations simpler by instantly aggregating all student data. In a traditional student laboratory experience, a lab group of 2-3 students must complete all aspects of investigation by the end of the period and the grade they earn will be directly dependent upon their ability to accomplish this. Students get little experience planning investigations because teachers must design them so they may be completed within the allotted time. By contrast, the CSCS model allows investigations to be conducted using whole class data. Students complete an investigation by examining entire class data. Using the CSCS model, teachers can divide data collection tasks among various lab groups so that the class can collect the necessary data even if individual lab groups are unable to do so.

**(4) Analyzing and interpreting data** - The CSCS model excels in teaching students how to analyze and interpret data. D’Alessio and Lundquist (2012) found that after using frequent CSCS activities, even students with limited science background begin to see data like experts see it. Students “made significant gains in data interpretation skills compared to a control group that did more traditional laboratory activities without the public comparison of data that defines CSCS.”

**(5) Using mathematics and computational thinking-** The CSCS model provides numerous opportunities to encourage the use of computational thinking. Rather than viewing an isolated set of data, students must use statistics to evaluate whole class data. Teachers include column headers in electronic quick-writes to perform basic computations on student input. (An electronic quick-write is a collaborative cloud-based spreadsheet in which columns represent individual questions and rows represent individual responses to those questions. (Herr et.al., 2012)) For example, if the teacher asks students to input their resting pulse rate, designated cells instantly report the maximum, minimum, and average pulse rates for the class while pre-defined graphs plot these statistics in a corresponding worksheet. Students learn to perform spreadsheet calculations by entering their own formulae in cells as prompted by their instructors. Rather than walking around the class to see student calculations, the teacher simply scans the spreadsheet and formatively assesses the computational reasoning of their students.

**(6) Constructing explanations and designing solutions** - Historians argue that Thomas Edison’s greatest invention was not the incandescent light bulb, motion pictures, recorded music, nor any of the other 1090 inventions for which he held patents, but rather the modern research laboratory in which he assembled top scientists and engineers to collaborate in the design and development of new products. Edison did not invent all of the items for which he received patents, but rather created an environment in which top scientists and engineers could collaborate to design solutions (Mintz, 2012). In a similar fashion, CSCS creates an environment where students work simultaneously on collaborative online lab reports, drawings,

spreadsheets, diagrams, photo albums, concept maps, presentations, wikis, and websites to construct explanations and design solutions.

**(7) Engaging in argument from evidence** - CSCS highlights the significance of evidence in learning science (d'Alessio, 2012; Herr et. al., 2010a, 2010b, 2011). In a traditional science classroom, students argue only from their own data, but in a CSCS classroom, students examine entire class data before generating hypotheses or making conclusions. Students learn to discern good data from bad data (d'Alessio, 2012) and learn the importance of patterns, trends, statistics, and outliers. Just as professional scientists evaluate their results in light of evidence from other laboratories, so CSCS students evaluate their results in light of evidence from other students.

**(8) Obtaining, evaluating, and communicating information** –CSCS creates an information-rich environment in which students work. Unlike a traditional classroom in which a single student is called upon to answer a question asked of the class, CSCS students are expected to answer all questions posed by the teacher all of the time. Rather than raising hands, students input their answers to the collaborative spreadsheet that both teachers and students read. Collaborative online documents provide the opportunity for the teacher to perform continuous formative assessments of student understanding (Herr et.al, 2012) while allowing students to see the input of their peers. As students respond to teacher prompts, they communicate not only to the teacher, but also to their peers. CSCS students respond in writing to each classroom question, and are also asked to evaluate the information communicated by their peers.

## **V. GENERAL INTEREST**

The National Research Council has stated that current science education in the United States “does not provide students with engaging opportunities to experience how science is actually done.” (NRC, 2012). The CSCS model, employing new collaborative web-based document technology, provides students and teachers the opportunity to readily collect and analyze large sets of data from multiple lab groups and class sections. Such resources may be used to create an environment that more closely resembles the collaborative environment of a professional scientific community in which researchers develop hypothesis and explanations in light of their own findings and those of their colleagues. The CSCS Model emphasizes scientific inquiry in an evidence-rich, collaborative environment that places greater emphases on interpretation, evaluation, and explanation. The CSCS model replaces traditional “cookbook” verification activities in which students work in isolated lab groups with discovery activities using student-generated procedures working in collaboration with multiple lab groups. The CSCS model provides an opportunity for students to experience how science is actually done by engaging in the scientific and engineering practices advocated in Dimension 1 of the Framework, namely (1) Asking questions (for science) and defining problems (for engineering) (2) Developing and using models (3) Planning and carrying out investigations (4) Analyzing and interpreting data (5) Using mathematics and computational thinking (6) Constructing explanations (for science) and designing solutions (for engineering) (7) Engaging in argument from evidence(8) Obtaining, evaluating, and communicating information.

## **BIBLIOGRAPHY (selected references)**

- American Association for the Advancement of Science. (1993). *Benchmarks for Science Literacy*. Project 2061. New York: Oxford University Press.
- American Association for the Advancement of Science. (2007). *Atlas of Science Literacy, Volumes 1 and 2*. Project 2061. Washington, DC: Author.
- Bransford, D., Brown, E., and Cocking, R. (eds.) (1999). *How People Learn: Brain, Mind, Experience, and School*. Committee on Developments in the Science of Learning, National Research Council. Washington, D.C.: National Academy Press
- d'Alessio, Matthew, and Loraine Lundquist (submitted for publication). Computer Supported Collaborative Rocketry: Teaching students to distinguish good and bad data like an expert physicist. The Physics

Teacher

- Herr, Foley, Rivas, d'Alessio, Vandergon, Simila, Nguyen-Graff, Postma (2012). Employing Collaborative Online Documents for Continuous Formative Assessments. Proceedings of the Society for Information Technology and Teacher Education (SITE). Austin, TX. March 5-9.
- Herr, Norman, Mike Rivas, Brian Foley, Virginia Vandergon, and Gerry Simila (2011) Using Collaborative Web-based documents to Instantly Collect and Analyze Whole Class Data. Proceedings of the 9th Annual Hawaii International Conference on Education, January 3-7, Honolulu, Hawaii.
- Herr, Norman, Mike Rivas, Brian Foley, Virginia Vandergon, Gerry Simil, Matthew d'Alessio, and Henk Potsma (2011) Computer Supported Collaborative Education - Strategies for Using Collaborative Web-Based Technologies to Engage All Learners. Proceedings of the 9th Annual Hawaii International Conference on Education, January 3-7, Honolulu, Hawaii.
- Herr, Norman and Mike Rivas (2010). Teaching the Nature of Scientific Research by Collecting and Analyzing Whole-Class Data Using Collaborative Web-Based Documents. Proceedings of the Association for the Advancement of Computing in Education, October 18-22, 2010, Orlando, Florida.
- National Governors Association Center for Best Practices, Council of Chief State School Officers (2010). Common Core State Standards. Washington D.C. National Governors Association Center for Best Practices, Council of Chief State School Officers,
- National Research Council. (1996). *National Science Education Standards*. National Committee for Science Education Standards and Assessment. Washington, DC: National Academy Press.
- National Research Council. (2012). *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*. Committee on a Conceptual Framework for New K-12 Science Education Standards. Board on Science Education, Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.