The use of collaborative web-based documents and websites to build scientific research communities in science classrooms.

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Abstract
New collaborative web-based document technology (e.g. Google® documents, Google® sites, spreadsheets, forms, and presentations) 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.

Introduction
In 1983 the National Commission on Excellence in Education assessed the quality of teaching and learning in American schools and concluded, "the educational foundations of our society are presently being eroded by a rising tide of mediocrity that threatens our very future as a Nation and a people". The Commission noted that our once unchallenged preeminence in science and technology was being overtaken by competitors throughout the world (National Commission on Excellence in Education, 1983), and recent economic developments seem to validate the Commission's concerns. In the quarter of century since the landmark "Nation at Risk" study was published, many have sought to assess and improve the status of science education in American schools, and many districts and states have increased curricular requirements in science and technology to address the Commission's concerns. In addition, many have sought to reform science education, giving greater emphasis to inquiry, data analysis, collaboration, and other aspects of investigative learning.

In an effort to establish national guidelines for reform in science education, the National Research Council commissioned the National Science Education Standards (National Research Council, 1996), which give great emphasis to the science laboratory experience and define inquiry as "the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work…", and "…the activities through which students develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world." (NRC, 1996). The National Science Teachers Association "strongly believes that developmentally appropriate laboratory investigations are essential for students of all ages and ability levels" (NSTA, 1996), and recommends that inquiry-based laboratory investigations should be "woven into every lesson and concept strand" and that laboratory activities should "focus on the processes of science as a way to convey content" (NSTA, 2004).

In the first consensus study of the National Research Council's Board on Science Education (2006), it was concluded that American science educators agree that that the purpose of the laboratory experience is to enhance mastery of the subject matter, develop scientific reasoning, understand the complexity and ambiguity of empirical work, develop practical skills, understand the nature of science, cultivate an interest in science, and develop teamwork abilities. Although the authors found strong consensus in the goals, they concluded "the quality of current laboratory experiences is poor for most students." They noted that teachers and laboratory manuals often emphasize procedures to be followed, but fail to emphasize learning goals related to the subject matter. In addition, they also found that few students experience laboratory activities that incorporate ongoing reflection and discussion with their peers and teachers. In summary, laboratory activities are often mere tests of "cookbook" procedures that are performed and evaluated in isolation from the work of other lab groups.

Although much has been written on the need for quality laboratory experiences, relatively few specifics have been offered to aid teachers in transforming the traditional laboratory classroom into a research community. We propose the use of collaborative web-based documents (e.g. Google® documents, spreadsheets, forms, presentations, and sites available at *docs.google.com* and *sites.google.com*) as a way of encouraging the development of a research community and addressing the consensus goals specified in America's Lab Report (NRC, 2006). In, particular, such collaborative resources require teamwork and can be used to develop an understanding of the nature of science as students work together to analyze their data in light of the findings of other lab groups and classes. The use of collaborative web-based documents to collect and analyze data, and to document and present findings, imitates the collaborative environment of a professional scientific community in which researchers develop hypotheses and explanations in light of their own findings and those of their colleagues.

What are collaborative web-based documents?

Various science teachers have advocated the use of spreadsheets and word processors in the writing of science lab reports to make comparisons, create graphs, sort data, draw conclusions and interpret data (Guglielmino, 1989, Kaeman, 2005, Scribner-MacLean et.al. 1989), and many teachers require their students to submit lab reports as word-processed documents with embedded tables and charts generated by spreadsheet programs such as Microsoft Excel®. Some teachers require that each student submit an individual lab report, while others require lab groups to collaborate and submit one report that represents the contributions of all on the team. In collaborative situations, students exchange data and versions of the lab report by exchanging files on flash drives or by email. If there are three people on a lab team, there can be three copies of each section of the lab report (figure 1). Each time a student edits one of these copies, a new version is introduced. The simplest way to avoid confusion is for a lab team to designate one student to compile everyone's work, but this works against the goal of developing teamwork through a cooperative, collaborative learning situation (Slavin, 1980). Fortunately, the introduction of interactive web-based document processing has created a new environment where all students in a lab group can work together simultaneously on a report.

In 2006 the information management giant Google acquired Upstartle, the software company which introduced the first web-based word processor, as well as the rights to the first web-based spreadsheet from 2Web Technologies (Google Press Center, 2006). In 2007 Google developed the first web-based presentation program (Bodis, 2007), and introduced all three as a free development suite known as Google Docs®. Any individual who opens a free Google account has an automatic link to Google Docs®. Users can develop documents, spreadsheets and presentations online using any modern browser, or can import them from OpenDocument files (.odt, .ods), common text file formats (.html, .txt, .csv, .rtf, .pdf), or proprietary formats such as Microsoft's .doc, .xls, and .ppt. Google docs are automatically saved to Google servers, but can also be downloaded in all of the same formats from which they can be uploaded. As with related Wiki technologies, a revision history is associated with each document so users can review, revise and/or reverse editorial changes.

Web-based documents like Google Docs (docs.google.com) offer teachers and students an environment in which they can work on the same file as they co-author lab reports and other projects. As students collaborate, each can see which revisions have been made by their colleagues, and can reverse or restore changes by selecting options in the revision history. Rather than working on original files and sending copies for peers to work on, all students work directly on the original (figure 2) so there is no confusion about the current status of the document. Such web-based development resources preclude the need for expensive software, since all one needs is a free downloadable browser such as Microsoft Explorer®, Firefox®, or Safari®.

Collecting and analyzing entire class data with web-based documents

Web-based documents provide the opportunity for instructors to design lessons that meet many of the commonly held goals of science educators. Teachers agree that the science laboratory experience should help *develop scientific reasoning* and an *understanding of the complexity and ambiguity of empirical work* (NRC, 2006). In traditional laboratory experiments, students work individually or in lab teams, and write lab reports based solely upon their own data. Although such reports may be valuable educational activities, they do not give students an understanding of the collaborative nature of scientific research. Scientists recognize the complexity of the natural world and realize that experiments must be performed many times and by many researchers before assigning confidence to observations or hypotheses. Scientists examine large data sets using descriptive and inferential statistics to document relationships and propose explanations, and recognize the inherent tentativeness and ambiguity of empirical work. Researchers view their findings in light of those presented by their colleagues, and reserve judgment until a preponderance of studies confirm their findings.

Fortunately, web-based documents provide an opportunity for students to understand the complex and collaborative nature of empirical research as they collect and analyze data from multiple lab groups, classes, or schools. Data collection can be simplified by survey tools, such as Google Forms®, that link directly to online Google Spreadsheets®. Teachers or students can develop forms in an online work center and then invite students to input their findings. Spreadsheets are created from the data, with records (rows) representing the lab groups, and fields (columns) representing answers to specific questions. Links to survey forms and their associated spreadsheets can be provided by copying document addresses to email messages, blogs, newsgroups or websites. Students reply to the online forms, and together build a single spreadsheet file that is shared by all. Within a few moments, an entire class can input their data, generating a table with as many records as there are laboratory groups, and as many fields as there are questions on the form. These data sets can be analyzed with built-in online tools and "mashup gadgets" (web application hybrids), or downloaded to each group for analysis with traditional tools such as Microsoft Excel®.

As students analyze their own data in the context of a larger data set, they are better positioned to understand the collaborative nature of the scientific endeavor, and the need for independent verification and repeatability of findings. Numeric data can be graphed and charted directly in the web-based spreadsheet, or downloaded by each lab group for individualized analysis. Students can then upload class data sets into their private accounts where only their partners have editing privileges. Thus, each lab group can perform a collaborative analysis of the entire class data independently from the other groups. The resulting charts and tables can be linked to the lab report that is developed in the document editor, and the entire project shared with the class by posting a link on a class blog or newsgroup. Lab groups can thereby share their findings with other groups and compare their analyses and conclusions with those of their peers.

Many classroom experiments call for the measurement or calculation of specific values, such as the density of water, the molar volume of a gas, the wavelength of a laser's light, or the parentage of root tip cells in mitosis. Students may notice that their values differ from those of other lab teams and thereby gain an understanding of the value of descriptive statistical measures, such as mean and standard deviation, when analyzing experimental data. As students graph class data using web-based spreadsheet tools, they may note bell-shaped distributions and gain a more intuitive understanding of the normal curve and basic descriptive statistics. Bimodal distributions may indicate the use of two different techniques while random distributions may indicate flaws in experimental design or implementation. Analyzing class data sets, students learn the complexity of the natural world and see the need for standardizing procedures and controlling for confounding variables.

Web-based documents can be employed to help students learn aspects of the nature of science and gain experience working in large teams. Scientists work in research laboratories that are part of larger networks and associations, and share their findings with their peers through journals and conferences. In the traditional college or school science classroom, only the instructor reviews student work. Web-based document technology provides students the opportunity to work cooperatively in the collection of data, and to electronically share their findings with their peers.

Teachers agree that a major function of the science laboratory experience is to help *students develop teamwork abilities,* but note that teamwork skills are rarely taught in schools and colleges (2006, NRC). Dickinson and McIntyre developed a 7-factor model to define and teach effective teamwork. In their model, *leadership* and *orientation* (acceptance of team members, norms, and goals) are considered input components in team building. *Monitoring*, *feedback*, and *back-up* (assisting the performance of other members) are considered intermediate processes for ensuring effective teamwork behavior, while *coordination* is considered the output component because it defines the performance of the team. *Communication* is considered a transversal component because it links all of the other components (Dickinson et. al., 1997). For many years, computer-supported collaborative learning studies have investigated the use of computer network systems to build collaborative teamwork environments, with most of the work focusing on distance learning efforts using tools such as email, video conferencing and electronic chat (Ellis et al. 1991, Silverman, 1995). More recently, researchers have found that wireless interconnected hand-held computing devices can be used to create environments that support face-to-face collaboration and the development of teamwork in traditional classrooms as defined by Dickinson (Cortez et. al., 2009), but little has been written of the use of "Web 2.0" applications in the process of teambuilding.

"Web 2.0" applications that are dynamic web-based resources designed to facilitate communication, interoperability, and collaboration on the World Wide Web. Interactive web-based document processors are Web 2.0 applications that provide an environment for collaboration, and educators can employ them to build teamwork skills that reflect the nature of science research labs. The following section provides a sample of how collaborative web-based documents can be used to cultivate a community of research in the science classroom.

Sample research activity employing collaborative web-based documents

Science educators encourage the use of inquiry-based laboratory activities as a way of engaging students in scientific research (Herr, 2008). Such activities often require the acquisition of much data, and are greatly enhanced when different lab groups pool their data for analysis. Inquiry activities, because of their emphasis on experimentation, data analysis, pattern recognition, and explanation, can be greatly enhanced through the use of collaborative web-based resources. In the following inquiry-based activity designed to answer the question, "What causes some things to float and other identically shaped objects to sink in water?", students (a) collect class data using *web-based forms*, (b) analyze and plot class data with *web-based spreadsheets and graphing tools*, (c) dialog online with their peers using *document-linked web-based chat*, (d) compose lab reports using *web-based documents*, (e) edit and examine revisions using the *revision history*, and (f) share their findings using *web-based presentation tools*. Examples of this and other activities are available online at *www.csun.edu/science/courses/docs.*

Rather than following a prescribed "cookbook" set of instructions, inquiry activities guide students to develop and answer their own questions. A common question that may be asked in a unit on force and motion might be, "What causes some things to float and other identically shaped objects to sink in water?" Traditionally, instructors introduce the concepts of density, buoyancy, and Archimedes Principle, and then proceed to answer the question in light of these concepts. An inquiry activity designed to answer the same question might involve the collection and analysis of information regarding materials that float and sink with the hope that students will find correlations between the properties of the materials and their buoyancy in water.

To answer this question by inquiry, students measure the mass and volume of various blocks (oak, pine, poplar, PVC, acrylic, iron, copper, etc.) and then place them into a water-filled container to see if they sink or float. They then bind combinations of these blocks with rubber bands and repeat the procedure (figure 3), plotting sinkers and floaters as two series of data on a graph of mass (measured in grams) vs. volume (number of blocks).

Although students may see correlations just by looking at their own data, trends become much clearer with the addition of data from other lab groups. To initiate the collaborative investigation, the teacher creates a (a) *web-based survey form* that links to a (b) *web-based spreadsheet*. As students enter data in the form, their data is recorded in the spreadsheet along with that of other students. Within a few minutes, all of the class data is collected and trends in the data can be seen. The students plot the data using the web-based spreadsheet tools, draw a border between the sinkers and floaters, then measure the mass to volume ratio for three different volumes of water and plot them on the chart. When they see that all three volumes of water fall on the dividing line between floaters and sinkers, they start to understand the concept of density, and why some cubes sink while others float. Students discover and define the concept of density and determine that for cubes, objects with a mass to volume ratio greater than that of water sink, while those with a ratio less than that of water float. By analyzing the entire class data they see the reliability of trends, see much sharper boundaries between floaters and sinkers, and draw more compelling conclusions that they can then compare with those of other lab groups.

Students write their lab reports as (c) *web-based word processing documents*. Each student on a team has responsibilities for writing a specific section (e.g., research question, methods and materials, data analysis, conclusions, etc.), and together they compose and edit a single document. Team members can log in to the document from home and dialog with their lab partners and classmates through an (d) *online chat* linked specifically to the document. Team members can examine the (e) *revision history* to see the edits introduced by their lab partners, and reverse changes if necessary. Finally, when a lab team has agreed upon a report, they can collaborate to compose a (f) *web-based presentation* that resembles Microsoft PowerPoint®. Each team member can make slides for his or her component of the report and then edit the work of others. Students can then share their work with their classmates either by making a presentation with a data projector, or simply by giving public access to their web-based presentation.

As students collaborate using web-based documents to collect, analyze, and plot data and to report and present their findings, they have opportunity to exhibit all seven factors of teamwork mentioned in Dickinson and McIntyre's model (Dickinson et. al., 1997).

Interactive web-based documents provide a medium that can be used to facilitate collaboration and teamwork between and among lab groups in both face-to-face and distance learning environments.

Employing collaborative web-based technologies in inductive and deductive laboratory activities

Web-based document technology (e.g. Google Documents, Spreadsheets, Forms, and Presentations®) provides an environment for collaboration, but teachers must develop appropriate activities and lessons if they plan to capitalize on the opportunities the technology affords. Virtually any inquiry-based inductive laboratory activity can be improved by the use of these tools. However, it is incumbent upon the teacher to develop effective lessons, and towards this end we recommend that teachers model after the sample activity presented in the preceding section. For example, an investigation may ask students to find the relationship between mass, length, and the period of a pendulum. Relationships that are invisible with the few data points collected by a single lab group become clear with the addition of whole class data. If each group measures the period of a pendulum using different weights and lengths, then students will have large data sets to analyze. Using *spreadsheet curve-fitting* technology, students can find the equations that best fit the class data. By analyzing whole class data, students can determine that the period of pendulum is independent of mass, but directly dependent upon the square root of the length of the pendulum. Such conclusions can be made quickly when working with whole class data, but may take very long if each lab group must independently generate all of the necessary data.

Although web-based document technology is best suited for use with inductive laboratory investigations, it can also be employed in traditional deductive laboratory activities to collect whole class data and quickly acquire class means, medians, and standard deviations. Students will note that class average values are generally closer to accepted values than are their own. For example, when determining the molar volume of a gas, the lab group with the best data in the class might get 22.9 L/mole (2% error), while the class average of 22.5 L/mole (0.5% error) is closer to the accepted value of 22.4 L/mole. Teachers can capitalize on this phenomenon to show the value of collaboration in scientific research, and can illustrate the fact that "accepted values" (e.g. growth rates, germination percentages, melting points, mathematical constants, etc.) are "average values" representing the work of many researchers.

The recent introduction of "*mashup*" technology introduces a host of new opportunities for science educators. A mashup is a Web application that combines data from one or more sources into a single integrated tool. For example, the mapping mashup gadget Map by Google® that is accessible in Google Docs®, integrates Google Spreadshseet® data with Google Map® data. Students can input their addresses into a form which creates a spreadsheet of street numbers, cities, and zip codes. The mashup then integrates this data with mapping applications to show on a map where everyone lives. Such data can be used not only to visualize distributions, but also calculate distances and other significant data. Mapping mashups are very useful for plotting fieldwork data, and one can expect an increasing number of mashup technologies to appear, making interactive web-based documents even more functional for use in the teaching of the sciences.

Conclusion

Collaborative web-based document technologies provide educators an environment in which to foster the development of a community of researchers. Google Documents® (*docs.google.com*) is currently the best suite of development tools, and one can be confident that these tools will continue to improve even as new tools are introduced by Google and other parties. The list of tools and capabilities continues to grow, and the introduction of third-party "gadgets" will further increase options for lesson development. Students who collaborate using web-based documents have many opportunities to learn about the value and techniques of teamwork in scientific research. In addition, they are more likely to understand the complexity and ambiguity of empirical work, and the true nature of scientific research.

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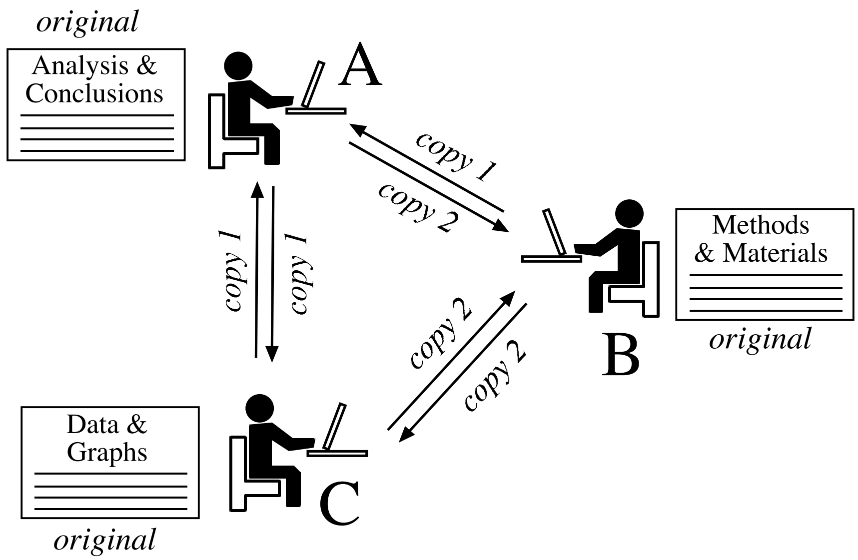

Figure 1 - Traditional approach in which documents are shared by email.
Note that many versions may be created.

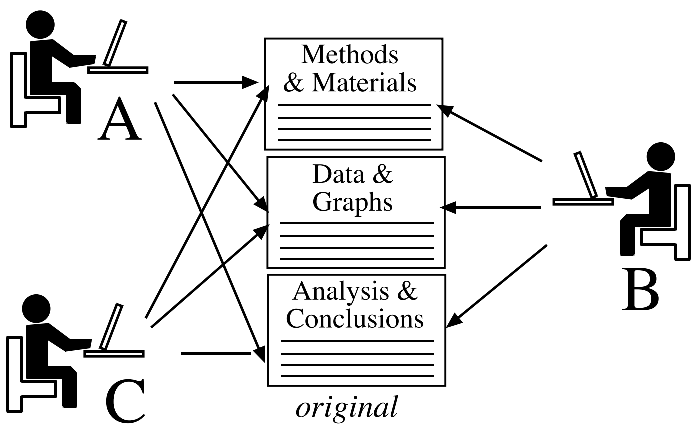

Figure 2 - Collaborative web-based documents.
Everyone works on the same docment.

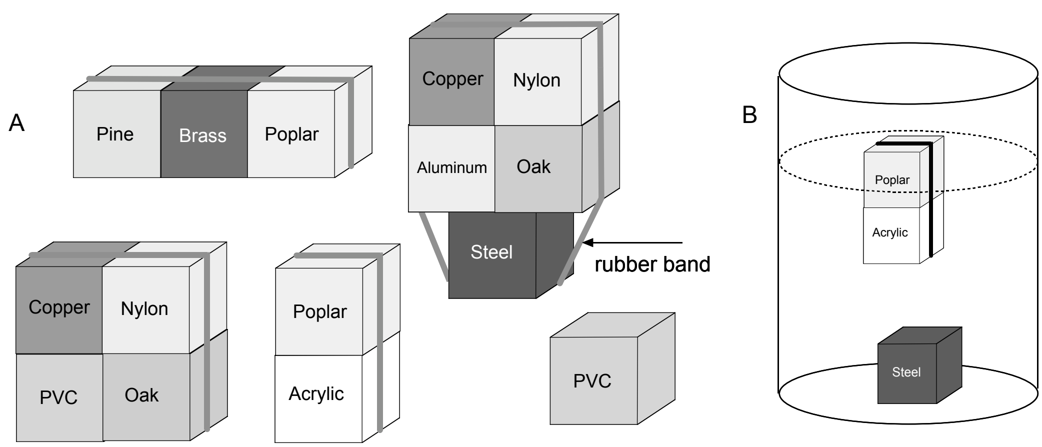

Figure 3 - Inquiry lab on density and bouyancy.
Class results are shared via an interactive web-based document.