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Using Collaborative Web-Based Documents to Instantly Collect and Analyze Whole-Class Data

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Abstract: New collaborative web-based document technology provides the opportunity to instantly collect and analyze large sets of data from multiple lab groups and class sections with speed and accuracy. Curricular resources can be developed that employ this emerging technology to create a classroom environment that mirrors the collaborative environment of a professional scientific community. Students gain a better understanding of various aspects of the nature of science when they view their findings in the context of a larger set of data collected by their peers. By engaging in laboratory activities in which they analyze whole-class data using wikis and collaborative web-based documents, students gain an understanding that the scientific enterprise requires collaboration, independent verification, and peer review. In this workshop, participants are introduced to a range of collaborative web-based activities in which they collect and analyze data submitted by their colleagues.

Introduction

American science educators agree that that the purpose of the laboratory experience is to enhance mastery of science content, develop scientific reasoning, build practical skills, cultivate interest in science, develop teamwork abilities, and introduce students to the complexity and ambiguity of empirical research and the "nature of science." Although there is strong consensus regarding these goals, it is clear that some goals are rarely realized. In particular, research shows that few laboratory activities provide attention to collaboration and the analysis and interpretation of data collected by others (National Research Council, 2006). Students generally work only with their own data and do not analyze it in context with data collected by their peers. Thus the opportunity to reach conclusions based on evidence is hampered by the quantity and quality of evidence at hand. Students will better develop teamwork abilities and am enhanced understand the complexity and ambiguity of empirical research by engaging in investigations that require collaboration, replication, and peer review. Laboratory activities that employ new collaborative web-based document technology to readily collect and analyze entire sets of data from multiple investigators can be used to provide students with a more accurate understanding of the collaborative nature of scientific investigation.

Rivas (2009), Lederman (2005), McComas (1998, 2005), McComas et al. (1998), Peters (2006), Bybee (2004), and others have described the *nature of science* and have encouraged its inclusion as a topic in the science curriculum. The following aspects of the nature of science are frequently mentioned in literature related to teaching the sciences. (1) Science involves the activity of explaining and predicting natural phenomenon. (2) Scientific knowledge is derived from evidence, and as a result our current understandings are durable but tentative. (3) Empirical evidence, accurate record keeping, and replication of experiments help validate scientific ideas. (4) The scientific enterprise requires collaboration, independent verification, and peer review. (5) Science is a creative endeavor, and there is no such thing as a single scientific method. (6) Science and technology are not the same, but they impact each other. (7) Because of social, historical, and cultural influences, science can be subjective and have bias. (8) There are realms of understanding, knowing, and belief that fall outside the scientific domain and thus science and its methods cannot answer all questions.

Although much has been written on the need for laboratory experiences that give students an understanding and appreciation of the nature of science and scientific research, few practical solutions have been proposed. Laboratory activities are generally selected because they match the curriculum and are feasible given the constraints of time and resources, not because they help students understand the nature of science. Fortunately, recent advances in collaborative web-based document technologies now provide educators the opportunity to develop laboratory experiences that require contributions from all members of the class. Students publish their data to collaborative spreadsheets where it is visible to their peers, and thus are able to analyze their own findings in light of entire class data. Students thereby learn the collaborative nature of science and realize that researchers must view their findings in context with those published by their peers. In addition, they see how collaboration between many researchers provides the opportunity to see relationships and trends in data that would otherwise go unnoticed.

The science teacher education program at California State University, Northridge, has developed a curriculum that uses collaborative web-based documents (e.g. Google® documents, spreadsheets, forms, presentations, drawings, wikis, and websites available at *docs.google.com* and *sites.google.com*) to create a classroom-based research community that addresses the consensus goals specified in America's Lab Report (National Research Council, 2006). In particular, the use of collaborative web-based documents to collect and analyze data, and to record 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.

Collaborative Web-Based Documents

Various science educators 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; Kademan, 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 instructors require each student to 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. 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 the same version of the 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 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 Firefox®, Safari®, or Internet Explorer®.

Collecting and Analyzing Large Group Data with Collaborative 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* (National Research Council, 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 percentage 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. By 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 (National Research Council, 2006). 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.

Web-based document technologies (e.g. Google Documents, Spreadsheets, Forms, and Presentations®) provide 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 instructor to develop effective lessons. 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 collective observations 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 Spreadsheet® data with Google Map® data. Students can input their addresses into a form that 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 science.

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 and collaboration in scientific research. As they work together with online data and analyses generated by their peers, they are more likely to understand the complexity and ambiguity of empirical work, as well as the need for accurate record keeping, replication, independent verification and peer review. Working in an online research community affords students the opportunity to better understand the nature of science and scientific research.

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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.

Web-based document technologies (e.g. Google Documents, Spreadsheets, Forms, and Presentations®) provide 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 instructor to develop effective lessons. 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 collective observations 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 Spreadsheet® data with Google Map® data. Students can input their addresses into a form that 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 science.

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 and collaboration in scientific research. As they work together with online data and analyses generated by their peers, they are more likely to understand the complexity and ambiguity of empirical work, as well as the need for accurate record keeping, replication, independent verification and peer review. Working in an online research community affords students the opportunity to better understand the nature of science and scientific research.

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