

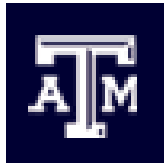
Online Scientific Mentoring: How Do Plant Scientists and Student Research Teams Communicate about Students' Scientific Investigations?

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Abstract

Scientific Inquiry Through Plants (SIP) is an interactive online learning community supported by the Botanical Society of America. "Wonder of Seeds" was the first SIP inquiry unit developed and field-tested by a team of plant scientists, science researchers, and K-12 teachers. In the field test, middle school through college students explored science through hands-on inquiry projects, mentored online by volunteer plant scientists. Seven scientists mentored 42 student research teams at four field sites. Student research teams entered project data in electronic journals and communicated with peers and scientists through an electronic discussion board on the SIP website. In this study, data from the field test was used to assess strengths and weaknesses of the protocols for data entry and dialog. Analysis of responses among scientists, student teams, and peers revealed patterns of discourse among the groups. Scientists offered encouragement, questions, advice, scientific information, and anecdotes. Student teams provided information on research progress, asked direct questions, sometimes provided additional information when asked for it, but rarely made conclusions or linked data from their experiments to their conclusions. This paper provides details of the discourse between scientists and student research teams which led to a set of suggestions made to the Botanical Society of America to improve the use of the on-line SIP resource in science classrooms.

Subject/Problem

Sustaining the curiosity of children and helping them develop the sets of abilities associated with scientific inquiry has long been a goal of science education reform (National Research Council, 2000). "Children need to be nurtured to fully develop their abilities to become real thinkers—to puzzle through problems, to see multiple ways of finding solutions, to gather and weigh evidence, and to apply and test scientific ideas" (National Science Foundation, 1999, p. 1). Unfortunately, many science experiences in school science fall short in providing students with "authentic" scientific experiences (Chinn & Malhotra, 2002). "Understanding the complexity and ambiguity of empirical work" (Singer et al., 2006, p. 77) was a new addition to the list of goals for laboratory experiences provided in *America's Lab Report*, published by the National Research Council. This new goal reflects the unique nature of science as a direct, contradictory response to the traditional, tried-and-true "cook-book-type" laboratory experiences children usually experience in classroom science, used to represent the "scientific method" as the one and only way that scientists think and act.

The committee thinks that developing students' ability to recognize this complexity and develop strategies for sorting through it is an essential goal of laboratory experiences. Unlike the other goals, which coincide with the goals of science education more broadly and may be advanced through lectures, reading, or other forms of scientific instruction, laboratory experiences may be the only way to advance the goal of helping students understand the complexity and ambiguity of empirical work. (Singer, 2006, pp. 75-76)

Unless classroom teachers have experienced authentic laboratory science themselves, they are often at a loss to direct open-ended laboratory experiences that allow students to seek answers to scientific problems that they themselves have identified. "The vast majority of science and mathematics teachers have never had an opportunity to 'do' science or mathematics in a real-world setting" (Krajcik et al., 2000; Mundry, 2003). Immersion into the world of scientists means knowing how to deal with ambiguity, reflect on surprising results, and feel okay with the idea that real scientific questions do not have answers. Scientists, who deal with complexity and ambiguity on a daily basis as they do their work, have much to offer. Bruce Alberts, President of the National Academy of Sciences, viewed scientists as those who can reinvigorate our school systems. "With the proper preparation and support, these scientists can immediately introduce inquiry into the curriculum, and they can help generate new types of professional development experiences for other teachers in their schools" (National Research Foundation, 1999, p. 12).

Time is another big issue for teachers in allowing students opportunities to think and act like "real" scientists (National Research Council, 1996). One-on-one support is often required for students to explore the world of investigating a scientific phenomenon on their own. When student research teams embark on problem finding and well as problem solving, back-and-forth negotiation and scaffolding among team members and with the teacher can appear overwhelming to the teacher. Time is the currency of the classroom. Allowing students time to design, debate, test, defend, and refine protocols for investigating their own questions about the world is in direct opposition to the pressures and perceptions that many teachers hold that "covering the material" is required when "teaching to the test" in our current era of high-stakes testing. Teaching "less as more," the slogan of Project 2061, becomes more difficult to manage as high-stakes testing takes its toll on robbing teachers of precious time that students need for thinking, reflecting, revising, and testing new ideas (Goldman et al., 1999).

Context

Two issues – time and teacher comfort with ambiguity and complexity -- were addressed head-on by plant scientists in the Botanical Society of America, who decided to design a website to support science education, scientific inquiry, and professional mentorship. The Society designed and implemented a proof-of-concept project that involved 137 students working in 42 student research teams from four science classrooms who shared their experiences of doing science with seven plant scientist mentors. "Wonder of Seeds" was the title of the inquiry unit developed and field-tested by a team of plant scientists, science researchers, and K-12 teachers. The Society provided teachers

with sets of various types of seeds to design student-generated investigations about seed germination and plant development. The Society also designed the Scientific Inquiry Through Plants (SIP) website (now available as archived data on the website, <http://www.PlantingScience.org>) to support student research teams as they shared their scientific journals and communicated with their peers and scientist mentors about their team projects.

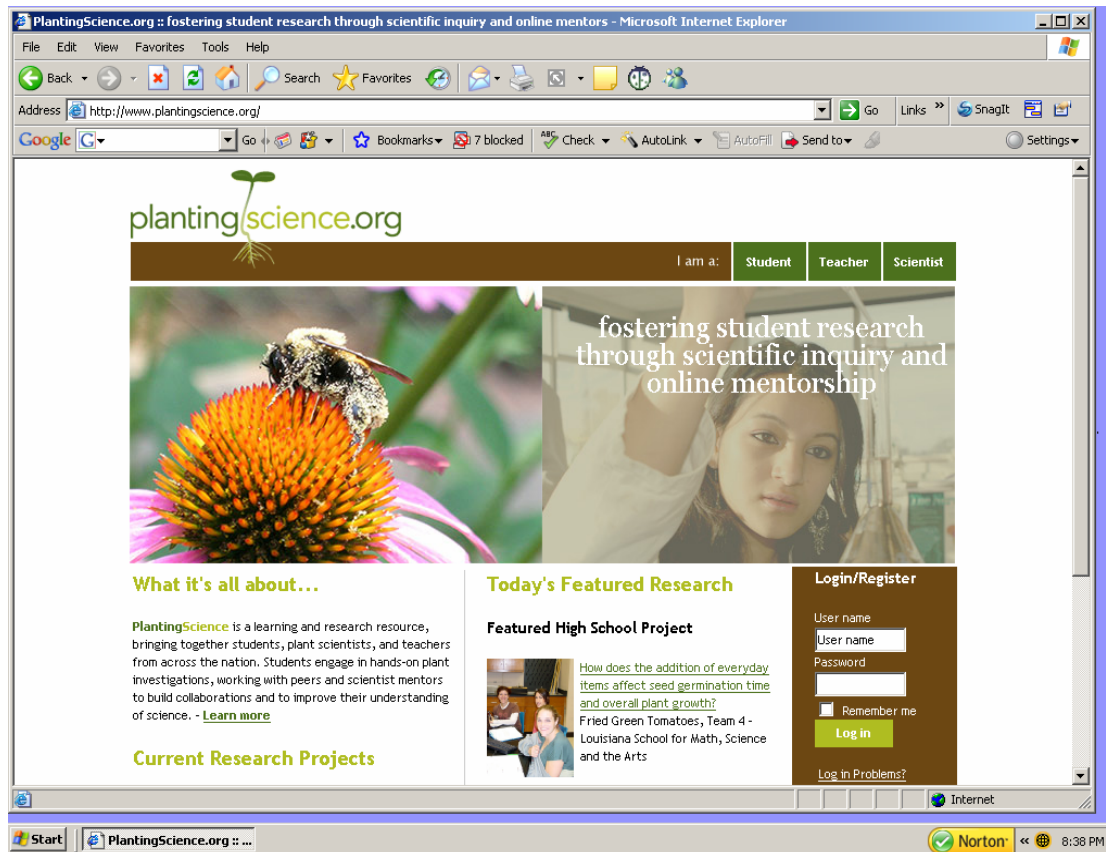


Figure 1. Homepage of the *PlantingScience* community portal currently housing archival data analyzed in the current study. (See <http://PlantingScience.org>.)

Classroom teachers involved in the SIP field test organized their students into research teams and provided basic structural arrangements in terms of space and time to work for students to independently pursue the answers to their self-generated questions. Neither teachers nor scientists, however, were expected to direct or guide the students' research investigations. Plant scientists volunteered to be professional mentors to share up-to-date knowledge and resources, to help dispel common misconceptions about plants, and to provide personally meaningful and significant outreach to student researchers.

The community portal provided space scientists and students to communicate about student inquiry teams' web-based journal postings. Figure 2 shows a sample communication page.



Comments	
Only logged in users are allowed to comment. register/log in	
Author	Comment
Dr. Carlie J. Phipps 	Subject: Introduction posted: October 10, 2005, 10:16 PM Hello! I'm Dr. Carlie Phipps, your personal science advisor for your team project (apart from your teacher, that is). I am an assistant professor at the SUNY Institute of Technology, SUNYIT is a relatively small college with about 2000 students in upstate New York, but I'm really a transplanted Midwesterner - I was raised in southern Illinois and went to school in Missouri, Ohio and Kansas. My doctorate is in botany, and my research is on fossil plants (paleobotany). I have done work on several types of fossil plants, including ferns and conifers, and am currently working on fungi that infect plants. I teach several different types of classes for students who aren't science majors, including botany, evolution, introductory genetics, and ecology. I learned about Sip3 at the Botanical Society of America conference this summer, and saw interviews from previous students who thought it was one of the most fun and informative lessons they did during the school year. I look forward to hearing from you and working with you on this project! Dr. Phipps
Pershing3	Subject: hey from Pershing 3 posted: October 26, 2005, 11:48 AM What is the temperature of the lamb and what is the sunlight to you...is it the window seal or out side?
Sisters7	Subject: hi posted: October 27, 2005, 11:31 AM The temperature of the heat lamp is 120 degrees
dude	posted: October 28, 2005, 4:26 PM good job guys!
Bill Dahl 	Subject: Great picture! posted: October 31, 2005, 9:23 AM Hi Cookie Monsters – Great picture. Can you tell us how you set this up to be so clear? How do your sprouts look now? Can you describe what you see? Can you provide us with an updated image or even a drawing? Are you collecting data on a spreadsheet that you can share? Thanks for your time in answering my questions. - Bill
Sisters7	posted: October 31, 2005, 11:56 AM Hi Bill... Thank you. We have a 5MP camera with a macro mode. That is how the seeds are so clear. Unfortunately , we accidentally forgot about them over the weekend. Thankx cookie monsters

Figure 2. A segment of dialog demonstrating online interactions among two research scientists (Dr. Carlie J. Phipps and Bill Dahl), the student research team (Sisters7), and a peer research team (Pershing3). The dialog is centered on the research of the Sisters7 team.

Dialog among student research teams, their peer teams, and scientists focused on data posted on each team's online journal. Journal entries were designed to include background research information that scientific teams had gathered from the literature, scientific questions, hypotheses, methods, results, and conclusions. Figure 3 provides a sample page from one group's scientific journal.

The "Wonder of Seeds" field test occurred during the fall semester of 2005. Teachers from four schools (one middle school, two high schools, and one undergraduate institution) organized a total of 42 student research teams (n= 137 total students), who were mentored by seven scientists. Groups of students received sets of different types of seeds provided by the Botanical Society of America with a set of instructions to formulate their own questions and design methods for answering them. (See <http://PlantingScience.org>.) Plant scientists were recruited by the Society to mentor one or more student teams, track student research teams' progress by reading their journal entries, and communicate with their student research teams about their experiments. Student research teams were encouraged by their teachers to communicate via the discussion board to scientists and peer research groups about their observations, thoughts, and findings.

Upon the completion of the field test, data sources were organized and made available to the authors of this paper with the purpose of making recommendations to the SIP Design Team about ways to improve the site for the purposes of enhancing students' understanding of plant biology and scientific inquiry. Data sources included dialog entries of scientists, student research teams, and their peer research teams; and electronic journal entries of each student research team. Team research journals included students' research of background information, scientific questions, hypotheses, procedures, results, analyses, and conclusions. See Figure 3.

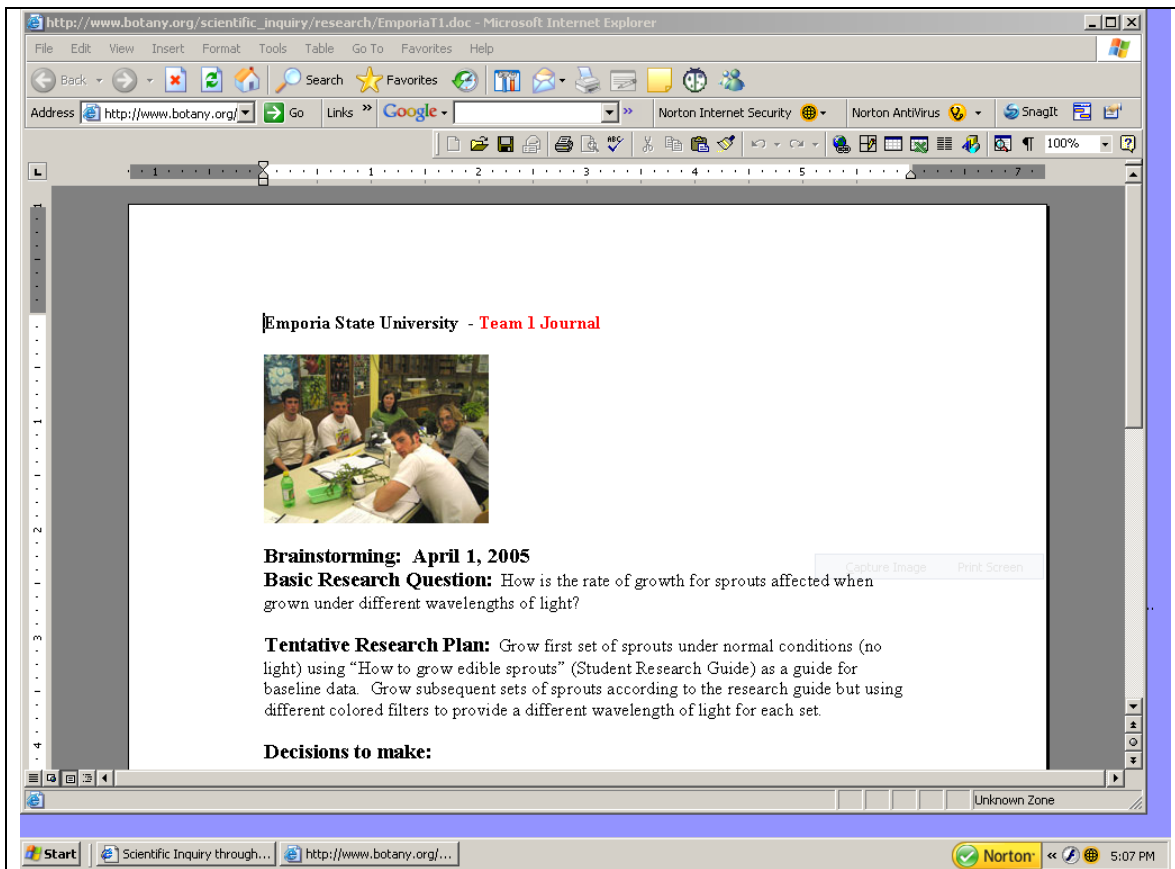


Figure 3. A sample journal page posted on the SIP Website from an undergraduate research team.

Methods

Research questions for this study focused on the dialog between scientist mentors, student research teams, and peer research teams. While journal entries centered these discussions, student research team's journal entries were not included in the analysis, as they were not directly related to scientists' or other research teams' interactions with each other as they occurred on the discussion board.

Two research questions guided the analysis of the data from the discussion board: (1) How do scientists talk with student research teams? (2) How do student research teams interact with scientists and with their peers?

To analyze data from the discussion board, individual dialog entries were segmented into “thought segments” representing intact comments or ideas made by scientists, by student research teams, and by peer research teams. The thought segments within each group of responses were coded by a method of constant comparison. Coded segments were then clustered into categories characterized by a label and represented by a generalized statement about the responses in that cluster. Exemplary comments were then chosen to best illustrate the general statement. The results of the analysis were shared with the SIP Design team, a group of research scientists, teachers, and educational research who meet on a regular basis to develop ideas for new open-ended inquiry projects to include on the SIP website.

Analysis and Findings

Fifty percent (n=137) of the 275 responses on the discussion board came from student research teams; 40 percent (n=110) from scientist mentors, and 10 percent (n=28) from peer research teams. Table 1 summarizes the number of responses from each of these groups by school type.

Table 1
Number of responses by school

School Type	Student Team	Scientist Mentor	Peer	Totals
Middle school	46	35	2	83
High school #1	38	42	11	91
High school #2	30	18	7	55
Undergraduate	23	15	8	46
Totals	137 (50%)	110 (40%)	28 (10%)	275

Responses from scientists

Forty percent (n=110) of the responses came from scientist mentors. Our analysis revealed nine categories of responses from scientists, as follows: (1) encouragement and reinforcement, (2) responses to teams’ questions, (3) advice, (4) requests for more information, (5) encouragement to think scientifically, (6) information about their own scientific research, (7) embedded factual information, (8) embedded procedural information, and (9) information about the history of science. Table 2 provides examples of each of these categories of responses from scientists.

Table 2
Examples of scientists' online responses by category

Category	Example
<p>Encouragement and reinforcement Scientists encourage and confirm results.</p>	<p><i>"Excellent! You know what you are looking for. As far as seeds and UV go, you may be the pioneers in this area. Choose some species and go for it!"</i></p>
<p>Responses to team's questions Scientists respond to student inquiry teams' questions (a) directly.</p>	<p><i>"Great question about why some are sprouting and others aren't. Sometimes small differences have consequences in germination. We could consider each bottle as having its own 'microclimate.'"</i></p>
<p>Responses to team's questions Scientists respond to student inquiry teams' questions (b) indirectly.</p>	<p><i>,,, " You mention that only 5 seeds germinated hydroponically, but I can't make a very good comparison with your soil treatment without knowing how many seeds you planted in each as well as the number that have germinated."</i></p>
<p>Advice Scientists provide advice about new experiments and/or methods/equipment the inquiry teams might consider, sometimes providing a rationale.</p>	<p><i>"Finding quality light sources for specific wavelengths had provided a challenge for us. We finally bought colored filters from Kodak. These are a bit pricey. Others have suggested using gels from stage lights."</i></p>
<p>Requests for more information Scientists suggest that students get more information, such as from literature searches and from students' own data, methods, and specific science content knowledge.</p>	<p><i>"I think that testing fertilizers is an interesting idea and it has far-reaching implications. Have you researched why fertilizers might affect germination time? Why are you assuming that fertilizer will promote growth?"</i></p>
<p>Encouragement to think scientifically Scientists encourage scientific thinking by requesting information about (a) factual information; (b) methods; (c) scientific question; (d) predictions.</p>	<p><i>"What do you think the effect of UV on plants is likely to be? Do you know what the effect of UV on cells is? Do you expect that the plants will react differently to different levels of UV?"</i></p>
<p>Information about their own scientific research Scientists provide information about their science in terms of what they themselves do, what their own scientific research interests are, and what scientific methods they use that are specific to the context of the experiment.</p>	<p><i>"We frequently look at percent germination as an indicator of how viable seed (is it a 'good' or 'bad' lot of seeds) or what is the effect of a specific treatment. Divide the number germinated by the total plants, x 100, to get % germination."</i></p>

<p>Embedded factual information Scientists embed factual information as they communicate with students.</p>	<p><i>“Seedlings turn green after they have been exposed to light. Chlorophyll, which is necessary for photosynthesis, takes a lot of energy to make. Until a seedling is exposed to sun it would be wasteful to produce chlorophyll...”</i></p>
<p>Embedded procedural information Scientists embed information about the general ways in which scientists work.</p>	<p><i>“I see you plan to include multiple seed samples in the two treatments (hydroponic and soil treatments). Replication is an essential component of sound science.”</i></p>
<p>Information about the history of science Scientists reveal information about the history and details of scientific discovery.</p>	<p><i>“When the Egyptians were building the pyramids, they took advantage of your observation that plant materials can absorb much water to cut stone for the pyramids. They would chisel holes in a few places along the line where they wanted stones to separate. Then, they hammered pieces of wood into the holes and allowed the wood to soak up water.”</i></p>

Responses from student research teams

Student research teams generated 137 (50%) of the total of responses in the field test. Five categories of student research teams emerged from the analysis of students' responses: (1) observations; (2) direct questions to scientists; (3) information about methods; (4) conclusions; (5) links between conclusions and data. Overall, student research teams very rarely responded directly to questions or comments made by scientists or their peers. Most frequent were reports of what happened in their experiments. Examples of student responses from each of the categories appear in Table 3 below.

Responses from peer research groups

Ten percent (n=28) of responses were generated by peer research groups. An analysis of the comments from peer research groups revealed two basic categories of responses: (1) encouragement, or (2) requests for information. Table 4 provides examples of peer research group comments.

Table 3
Examples of student responses by category

Category	Example
<p>Observations Inquiry teams report what happened in their experiments.</p>	<p><i>“After soaking the seeds in water now the real questions come, which seed will grow the most over a period of time? Some of our seeds are sprouting; some are not. We are making great progress, like some of the skins are coming off.”</i></p>
<p>Direct questions to scientists Inquiry teams ask direct questions to scientists related to the results.</p>	<p><i>“Are there any circumstances under which the shoot should grow first? Why are the roots white even though they are above ground and could photosynthesize? Are the plants producing nitrogen yet and if not when do they start? Does the size of the seed affect how big the plant will get when it is an adult? Does the environment affect how big the plant will get?”</i></p>
<p>Information about methods Inquiry teams provide more information when asked about their scientific methods.</p>	<p><i>“We realized that measuring only four seeds from each batch makes no sense, so we have started to measure all the seeds of each color in order to make our averages more accurate. We hope this clears up any problems you had with our data.”</i></p>
<p>Conclusions Student inquiry teams make conclusions that answers the scientific question (rarely); and (even more rarely) link data to their conclusions.</p>	<p><i>“In conclusion we have found that good old-fashioned water does the job the best when growing sprouts. If we were to do this inquiry again we would have observed and rinsed them twice a day because we might’ve caught when the drying out had taken place. We also would have used natural mineral water because it does not have sodium in it and therefore would not create another variable in our inquiry.”</i></p>
<p>Links between conclusions and data Student inquiry teams respond to the questions or comments that scientists or their peers make (very, very rarely).</p>	<p><i>“You asked in your comment, do we have a control group. Yes, our control group was given distilled water. This will allow us to compare the sugar solution and splenda solution to a control with no variables.”</i></p>

Table 4
Sample responses from peer research groups

Category of response	Sample response
<p>Encouragement Peers encourage and confirm the results of other student inquiry teams.</p>	<p><i>“Good luck on your data collection! We are growing red closer and monitoring the germination percentages of the different colors of clover seed.”</i></p>
<p>Requests for information Peers ask questions of the student inquiry teams about more data or specificity about methods.</p>	<p><i>“This is an unusual, but cool experiment. Why do you think the average length of the water-grown corn seedlings is less than the length of all the others? I hope that you can make some sort of conclusion that will seek to explain this problem.”</i></p>

Recommendations

At the level of the scientist mentor, we recommended that scientists continue their good work. Scientists' responses to student inquiry teams were timely and pertinent. Many of their responses prompted student inquiry teams to think and work like scientists. We also recommended that scientists whenever possible continue to offer information about their professional lives, about how they have solved similar problems in their own laboratories, and about how they have progressed in their own lines of inquiry. Information about the nature of science in general, such as how scientists control variables, or think through alternative hypotheses, was also shared with young learners. On the whole, we saw no problems with the level of engagement of the scientists. The evidence pointed to a strong commitment within the seven scientist volunteers to engage in dialog with the student inquiry groups.

As for the student inquiry groups, however, we believed there was still much to be learned by students in the ways of dialog with scientists and with their peers. Wonderful questions, posed by both scientists and peers, were not answered well or at all by most student inquiry groups. We felt that there were way too few examples of fruitful dialog, such as the one that follows.

Team: "When we returned to class from the weekend I went over and checked the growth of our seeds. The control group with distilled water showed growth in the form of sprouts. However, none of the seeds in the sugar water showed growth, and only one in the splenda water showed a sprout. A question that this brings to mind is that could this be due to ph levels in each of the solutions? Ph levels can be easily tested, this may be a direction we need to take."
(ESU462105958)

Peer #1: "hi. i just went over your journal right now and everything looks good. But I heard in class that you guys were starting the experiment over, so are you using the same things or something else. ... good luck with the new experiment." (ESU4621051104)

Peer #2: "I think that the experiment is a good idea, however I wanted to know what the importance of having the sugar solutions added to the plants would have on their growth. I also wanted to know if the plants were going to be stored in a dark room, to really control the light source that was being used, or was there also alternate light (the ceiling lights) that would also come into effect?" (ESU4621051115)

Scientist: "I'm curious to know why you want to test different sugar solutions? How did you arrive at this experiment? I'm glad to see you are controlling multiple variables. Do you have an explicit hypothesis to test?" (ESU4622051013)

Team: "Today there is much research on the ill-effects of artificial sweeteners. Splenda is now a substitute for aspartame, which many believe can be the cause of serious health problems for humans....." (ESU462705519)

Discourse in which ideas, data, and conclusions were argued and shared, such as the one above, rarely occurred. Common to students engaged in other forms of inquiry as well, instructional scaffolding has often been suggested to enhance learners' abilities to use evidence in support of their conclusions (e.g., Krajcik et al., 2000; Millwood & Sandoval, 2005). Student inquiry groups, for the most part, reported on what happened to

their seeds with little elaboration. They requested answers from scientists to a very few questions. We found student inquiry groups to be largely unresponsive to questions and comments from scientists and peers and to be uncommitted to the dialog process. Furthermore, when student inquiry groups did engage in the dialog, their responses were basically uninspired.

These findings regarding the responses of student inquiry groups led us to make suggestions to the SIP Design Team regarding the materials they might provide to classroom teachers engaged in the SIP project (now named *PlantingScience*). We suggested that teachers also have on-line opportunities to reflect on the value of the dialog between scientists and their students, to themselves as well as to their students. Scientists can provide immediate information that is rich, thorough, accurate, complex, and directly related to students' work. SIP teachers can also provide immediate information to other SIP teachers that is directly related to their students' work.

We also recommended that SIP encourage teachers to take time to discuss in class the information that the dialog between scientists and student research groups brings to the classroom, emphasizing the value of information that comes directly from the minds of actual scientists who have spent their lives' work doing what students are trying to do in their classroom inquiry projects. We recommended explicit instruction in which teachers would show examples of what *could* happen in terms of interchange of information, answering scientists' and peers' questions, and responding to requests for more information. Furthermore, we found so much information in the dialog from scientists about the nature of science and how scientists do their work that we recommended to SIP that they encourage teachers to spend some time in class reviewing what the scientists have told their mentored teams about how science is done. Several entries provided descriptions of how scientists do their work, and in some instances scientists provided a historical background about some aspect of scientific discovery. This information, which is shared conversationally in the dialog, could be emphasized in class through large-group classroom discussion. Teachers might ask students to find instances in the dialog where scientists have talked about what they do and how they do their work in order to reinforce important understandings about the nature of science as a unique enterprise engaging individuals who are committed to lives of discovery and investigation.

Furthermore, SIP could also provide information on their website for teachers revealing ways to encourage and reward student inquiry teams who engage in dialog with scientists and with their peers. For example, teachers could demonstrate the role of student inquiry teams in the dialog process and perhaps link information about assessment of student participation based on expectations that students will engage in dialog with scientists. Teachers might use a simple rubric linking what is expected with how a teacher might "grade" students' participation in the dialog. The rubric could provide examples of *Expected* dialogs, explaining that questions from scientists and peers are to be answered and information provided that is thorough and well described. Examples of *Exceeding Expectations*, or dialog which goes beyond that which is expected, could also be discussed; as well as dialogs that are *Approaching Expectations*,

and those where *Few Attempts* are made. Perhaps even equating the *Exceeding* category to an “A,” the *Expected* to a grade of “B,” and so on, might assist teachers in elevating the value of a dialog that is information rich, thorough, and interactive. In the present atmosphere of “grading” students based on their performance, these suggestions might provide teachers with concrete ways to support student learning.

In regard to the responses of peers, again we would go back to the teacher’s role in encouraging peer responses, and perhaps rewarding students who ask questions that engage their peers in dialog about some aspect of their scientific work. One of us (CLS) has had great success in the early weeks of the semester by assigning undergraduate students on a weekly basis to engage in a dialog on a particular topic in which they have to (1) offer new information in the dialog, and then (2) respond to at least two others’ offerings in some way by elaborating on the information, requesting more information, or offering an alternative viewpoint. With undergraduate students, these “assignments” have been necessary for just 2-3 weeks, after which time the students have actively communicated with each other about tasks to complete, readings which have provoked questions and responses, and so on. Electronic dialog is a very new skill to many public school students and teachers that has come about with newer advances in technology. While students may be quite familiar with communicating outside of class about the current events of their lives, the idea that students might communicate about school events, such as those occurring before their eyes in hands-on inquiry settings, may be new to them. Dialog for learning purposes and exchange of information may require some preliminary discussion and instructional scaffolding.

Contributions to the Teaching and Learning of Science

The results of the field test indicated that scientists were the best prepared to engage in the mentoring experience. Their comments to the student research teams were enthusiastic, useful, appropriate, encouraging, informative, and authentic. All evidence pointed to a strong commitment on the scientist mentors’ parts to support students’ pursuits in their authentic investigations. The analysis showed that students, on the other hand, still had much to learn about the processes of inquiry (e.g., National Research Council, 2000) and about ways to make the most of the mentoring relationship offered to them by SIP. For the most part, student research groups did not answer the excellent questions ask by scientists and peers. Research groups’ conversations with scientists and peers were not robust, elaborative, or generative. There was little evidence that student research groups took the questions seriously. Many questions, which could have been useful in the research groups’ pursuit of an answer, were not answered at all. Overall, trends in student research groups’ responses indicated a lack of understanding about the value of the mentor and a need to develop online communication skills that could be used to learn more *from* their scientist mentors and *about* the scientific work they were doing. Results of the field test led us to conclude that the role of the teacher in the mentoring process should be changed to be much more active, particularly as it related to the dialog process.

Communications about the findings of our research have led to significant revisions in the way the Botanical Society of America has structured the PlantingScience website. An information-rich section specifically designed was added for teachers to assist them in scaffolding their students' research projects. The website also provides examples for mentors of meaningful dialog, suggests classroom incentives for students to use the mentoring process as a way to improve their research efforts, provides rubrics for teachers to assess or "grade" students' participation with scientists, and lists ways that teachers can use particularly engaging dialogs and comments from scientists to enhance students' understanding of plant biology and scientific inquiry. A new student section has also been added to provide information to students about how to think and work like a scientist, keep a science journal, design an experiment, collect data, and make meaningful graphs.

Summary

Scientific Inquiry Through Plants (SIP) is an innovative project initiated by a professional scientific society to enhance novice learners' understanding of science through the study of plants while engaging in self-directed inquiry. SIP allows students to experience the authenticity of science, including its ambiguity and complexity, using scientists as mentors. K-12 classroom science teachers often lack the experience and time to orchestrate student-generated research that allows students to think and act like real scientists. The research reported here suggests that on-line, customized, individualized mentoring from scientists has promising possibilities in terms of providing teachers with the support they need to facilitate students' classroom research projects. We recommended that SIP direct some of their support to teachers with resources that are provided on-line as well as opportunities for dialog, similar to that provided for students but focusing on suggestions and recommendations for ways to improve students' experiences while working online with scientist mentors. The results of this analysis led us to make recommendations about ways to enhance dialog between scientist mentors and students and to improve the website. More significant to us, however, is that the results have led us to reconsider and recognize the power of the classroom teacher in enhancing their students' online learning. Our results tell us that the tasks of learning must be shared between all engaged in the teaching and learning process: classroom teachers, students, and scientist mentors who have volunteered out of their own personal commitment to sustain the curiosity of young learners while helping them develop the sets of abilities associated with scientific inquiry.

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