planting science

2009 PROGRESS REPORT

Submitted May 2009 to Monsanto Fund
by William Dahl, Executive Director, Botanical Society of America

I. PROJECT ACTIVITIES OVERVIEW

Key Inquiry Development Activities Reported in Dec. 2008 Progress Update:

- **Conducted beta field-testing of Rapid Cycling Brassica Strand of Genetics unit (Oct.-Dec. 2008).**
- **Continued development of Arabidopsis strand, with new collaboration from Dr. Erin Dolan of Partnership for Research and Education in Plants for content and field-testing.**
- **Identified teachers and mentors to participate in field-testing of both Rapid Cycling Brassica and Arabidopsis strands of Genetics unit for Spring 2009.**
- **Secured commitment from scientists and Teacher Leaders for 2009 teacher workshops.**
- **Revised comprehensive plan for a Curriculum Development and Deployment.**
- **Identified a qualified curriculum coordinator and a writer for Curriculum Development Team.**

Overview of Inquiry Development Activities Since Dec. 2008:

- **Held Jan. planning meeting for Curriculum Development Team (Teresa Woods—Coordinator, Sandy Honda—Writer, C. Hemingway—PlantingScience Project Director) in St. Louis. Refined curriculum inquiry requirements, development, and review guidelines.**
- **Field-tested a revised Rapid Cycling Brassica strand of new Genetics Unit in one classroom (working with Dr. Paul Williams of Wisconsin Fast Plants, teacher Kathy Vanderloop of Appleton West High School, and graduate student mentors M. Brown and A. Robertson).**
- **Drafted and field-tested Arabidopsis strand of the new Genetics Unit in two classrooms (working with Dr. Larry Griffing of Texas A&M University, teachers Allison Landry of Louisiana School for Math, Science and the Arts and Toni Lafferty of C.H. Yoe High School, and mentors J. Lando, Genevieve Walden, Courtney Leisner, Marshall Sundberg and Diana Jolles).**
- **Organized, coordinated, drafted, and field-tested new Pollination Unit in one classroom (working with Dr. Beverly Brown of Nazareth College and teacher Valdine McLean of Pershing County High School and graduate student mentor Nick DeBoer).**
- **Planned and successfully recruited 16 teachers for 9-day teacher professional development session, which will feature genetics and pollination inquiries whose development is described here. Engaged scientists and Teacher Leaders to share their expertise with participating teachers.**
- **Identified scientist contributors for 2 topics: Marshall Sundberg of Emporia State University, Celery Challenge; Renee Lopez-Smith of Southern Illinois University, C-fern Spore Investigation.**
- **Coordinated Spring PlantingScience session, the largest to date with 29 teachers, 1237 students, and 120 scientist mentors.**
- **100% (n=13) of the 2008 institute teachers implemented inquiry materials in the classroom and participated in online inquiry sessions, 5 teachers implemented both fall and spring. Continued relationship building, now 10 societies and organizations partner in PlantingScience.**
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II. Curriculum Writing, Field-Testing, and Disseminating Activities

The specific objective of the PlantingScience activity supported by the Monsanto Fund is to:

Develop and test inquiry teaching and learning resources that integrate plant science content and process and address National Science Education Standards: We aim to improve understanding of plant biology and the process of science and to escalate the significance of plants in classrooms. We will develop and field test a set of engaging, standards-aligned online (downloadable) materials that allow teachers to replace or supplement current lessons with flexible open-ended, active-learning approaches using plants as model organisms.

Curriculum Development Team Organization, Plans, and Progress.
Development of a suite of engaging, standards-aligned plant curricular modules that support inquiry science experiences in the classroom and science communication online is critical to the overall accessibility and success of the PlantingScience program. A significant update in the project activities has been to revise the curriculum development plan to secure expertise of a Curriculum Coordinator and Curriculum Writer who will work closely as a team to shepherd scientist-teacher teams through the development, field-testing, review, and deployment cycle. Contracts were signed in January. Teresa Woods is now serving as Curriculum Coordinator consultant, and Sandy Honda is serving as consultant for conceptual design and web delivery of written materials.

In late January 2009, Claire Hemingway brought together Teresa Woods and Sandy Honda in St. Louis to meet other members (W. Dahl and J. Potratz) of the PlantingScience team, review of the status of curricular units, and refine guidelines for inquiry materials and development. C. Hemingway provided T. Woods and S. Honda with documentation of prior inquiry drafts and field-testing materials and feedback from participants. Together we identified templates to support inquiry development (relying primarily on *Understanding by Design* worksheets) and review (relying on a combination of Biological Sciences Curriculum Study and National Science Education Standards materials).

T. Woods subsequently provided the new supporting documents and individual timelines to the three inquiry-writing and field-testing teams, coordinated materials for field-testing classrooms and mentors, and facilitated weekly conference calls for the inquiry teams. Additional changes and support mechanisms that are now in place for inquiry writing an field-testing teams include (1) providing each with a WetPaint wiki to facilitate the sharing of material and (2) integrating multiple graduate students/post-doctoral researchers more closely into the team to perform the same investigations and mentor student teams.

The latter improvement is proving invaluable, with immediate pay-offs to improve the efficiency and accuracy of protocol testing, enhance connections between classroom teachers and scientist mentors in the program, and identify and support young plant scientists with an interest in science education. A strong partnership and mentorship formed between Dr. Paul Williams of Wisconsin Fast Plants and graduate student Amber Roberston, which has resulted to Amber's extensive involvement working on the curricular materials with Dr. Williams and her co-presentation of them during the up-coming summer institute. We anticipate additional leadership roles will emerge among members of the Master Plant Science Team, in particular, but also in the larger scientist mentor pool.

Synopses of the field-testing activities and big ideas of each inquiry are below.

Spring 2009 Field-testing of two Genetics strands and Pollination Module.
While reinforcing core content of Mendelian genetics, these strands also raise the bar for genetics curricular materials by more rigorously introducing quantitative traits and polygenic inheritance and allowing students to compare and contrast traits and patterns of inheritance. The two strands of the Genetics Module share core big ideas, rely on similar genetic markers for students to observe both discrete and continuous traits (purple anthocyanin pigments and plant hairs), and explore a combination of Mendelian and polygenic patterns of inheritance. These are investigations as sample sized required

to reveal inheritance patterns require pooling of class data, although thought-experiments to open the investigation are offered. Differences in the plant breeding system, genetics, and uses as model plants in the classroom and laboratory underlie differences in the two strands.

Big Ideas

- Organisms have a life cycle by which they potentially grow, reproduce (pass genes to offspring) and die
- An organisms exists as an expression (phenotype) of its inherited genes interacting in an environmental context
- Phenotypic variation in exhibited among individual organisms in a population
- Evolution occurs through selection within the context of variation of specific phenotypes within a population (stressed in RCB strand)
- Individuals with the same genotype tend to express less variation among themselves than among different genotypes (stressed in Arabidopsis strand)
- Traits that are selected for are often expressed in concert with other traits that may or may mot be selected for

"Genetics, Environment and Evolution: Phenotypic Variation in Rapid Cycling Brassica" Genetics Strand – this 3-10 week module is a guided investigation of the inheritance patterns of discrete and continuous traits

Core Scientist-Teacher Team: Paul Williams, Wisconsin Fast Plants; Kathy Vanderloop of Appleton West High School and her Genetics elective class.

Supporting graduate student scientists shadowing classroom experiments and mentoring students: Amber Robertson of University of Wisconsin, Madison and Michelle Brown of University of California, Riverside.

The full inquiry growing the F1, recording data on hair counts and anthocyanin presence or absence, selecting for the hairiest plants for mating, making crosses, and growing the subsequent F2 generation to record data on F2 plants requires 10 weeks. Shortened adaptations to focus on particular learning goals with integrity for learners at particular levels have been identified.

K. Vanderloop provided an extensive teaching portfolio following the fall trial with her Applied Genetics class with junior and senior high school students. Based on review of the fall field-test, the RCB strand was modified to include high- and low-nutrient environment conditions. The spring field testing is in final phase, with Kathy Vanderloop's students having planted seeds from the F2 at the end of April and students preparing to make final counts of hairs on first true leaves of F2 plants. Students will then compare hair counts of F1 and F2 plants to calculate heritability and selection gains. We anticipate reviewing materials and feedback from the spring participants in the third week of May.

"Genetics, Environment and Evolution: Phenotypic Variation in Arabidopsis Recombinant Inbred Lines" Genetics Strand – this 3-10 week module is a guided investigation of the inheritance patterns of discrete and continuous traits

Core Scientist-Teacher Team: Larry Griffing, Texas A&M University; Allison Landry of Louisiana School for Math, Science, and the Arts and her elective science methods class; Toni Lafferty of C.H. Yoe High School and her freshman introductory biology class.

Supporting scientists shadowing classroom experiments and mentoring students: Genevieve Walden of San Francisco State University, Dr. Jason Lando of Environmental Protection Agency, Dr. Marshall Sundberg of Emporia State University, Courtney Liesner of University of Georgia, and Dr. Diana Jolles of Portland State University.

The Arabidopsis strand differs significantly from the Rapid Cycing Brassica strand in that students do not perform genetic crosses, but examine phenotypic variation among ~40 recombinant inbred lines and the parental Columbia and Lansberg lines. During spring field-testing, Toni Lafferty's class attempted only the 3-4 week petri dish growth system, while Allison Landry's class, along with mentors G. Walden and J. Lando, attempted both the short petri dish and the extended peat pot systems. Mold was a significant problem for plants in petri dishes, while the peat pot growth system was more successful. Growing plants in the peat pot system have the additional advantage that students may record data on the erecta phenotype which is present as plants develop as well as conducting hair counts and sugar assays to test for anthocyanin. T. Lafferty's students examined survival rates among the RILs, while A. Landry's students data collection was most successful for hair counts, but inconclusive for the other traits. A. Landry's students uploaded final PowerPoint presentations to the project website summarizing their initial ideas about whether the traits under investigation were continuous or discrete and their research findings about the distribution of the traits across the RILs and parental lines. The primary outcome of this alpha testing was to identify protocols that work in high school classrooms. Several protocol and growth system improvements were put in place during weekly conference calls and additional refinements will used during the summer institute.

"Pollen: Where does it come from? Where is it going?" Pollination Module – this 3-4 week module progresses from guided to open

Core Scientist-Teacher Team: Beverly Brown, Nazareth College; Valdine McLean of Pershing County High School and her biology class.

Supporting graduate student scientist shadowing classroom experiments and mentoring students: Nick DeBoer of University of Hawaii.

Starting materials for the Pollination Module included pre-existing pollen materials developed for the Plant IT Careers, Cases, and Collaboration project (a collaboration among the Botanical Society of America, BioQUEST Curriculum Consortium, and Texas A&M University) http://www.bioquest.org/myplantit-2008/july-08-2008.php and pollinator movement experiments Dr. Beverly Brown has conducted with her students at Nazareth College. Alpha testing of the Pollination Module in Valdine McLean's classroom this spring involved only the pollen investigation strand. The pollen module was sequenced for students to get hooked on the relevance of pollen to their own lives and become familiar with the scientific toolbox (microscopy, data sources) and investigation skills (where to find pollen, how to collect pollen, how to observe pollen, and how to test its viability) through teacher-guided activities in weeks 1 and 2. The mini investigative case "Paul's Puzzle" served as a hook and students used online data and maps to correlate allergies with atmospheric pollen levels. Students then examined flowers and cones anatomy to identify pollen and relationships of plant parts. Students then stained pollen for examination under microscopes and used solutions to observe pollen tube growth. A bridge phase to review concepts and skills helps orient students to the types of questions scientists study and provides structure to brainstorming for student-directed questions. The culminating phase is the opportunity to engage in open inquiry in teams. Each of the six teams in V. McLean's classroom asked a unique question. The teams investigated the relationship between flower size and pollen size, the relationship between pollen trap placement in the local school yard and pollen type collected, the distribution of pollen types across the town, the relationship between atmospheric pollen levels across regions of the US with different wind patterns, how sugar concentration influences pollen tube growth, and the effect of micronutrients on pollen tube growth.

Big Ideas

- Pollen is integral to the life cycle of angiosperms and gymnosperms
- Pollen from outcrossing plants is moved from plant to plant by wind, water, animals
- Pollen viability depends on many factors
- The study of pollen (palynology) can reveal the interconnectedness of
    - Biotic and abiotic factors in the environment
    - Local, regional, and global geography
    - Diversity and distribution of plants

The Rapid Cycling Brassica strand is in its final weeks. Field-testing of the Arabidopsis strand and Pollination module are complete. During May 18-20, T. Woods and C. Hemingway will meet to review field-testing materials, feedback from teachers and mentors, and student work on the web, and prepare drafts for use at the summer institute. S. Honda will participate via one or more Tokbox online video conferences.

Summer 2009 Teacher Institute Plans.
Genetics and pollination are the two inquiry modules scheduled for the second PlantingScience Summer Institute for Teachers, which will be held June 8-16, 2009. Commitments have been secured from Dr. Paul Williams of Wisconsin Fast Plants and Amber Robertson of University of Wisconsin, Madison (leading Wisconsin Fast Plant Strand of the Genetics unit), Dr. Larry Griffing of Texas A&M University (leading Arabidopsis strand of the Genetics unit), and Dr. Beverly Brown of Nazareth College (leading Pollination unit). These scientists will lead the intensive science inquiry immersion experience during the first 5 days of the summer institute, along with significant input from Teacher Leaders Kathy Vanderloop, Toni Lafferty, and Allison Landry. Teacher Leader Valdine McLean has school schedule conflicts and is unable to attend the summer institute, but we will attempt to connect Valdine via ToxBox video calls.

The Curriculum Development Team of Teresa Woods and Dr. Sandy Honda will attend the summer workshop to observe how teachers engage with the plant materials, curricular guides, and scientists in order to inform next stage of writing and field testing. Woods and Honda will additionally contribute their expertise to sessions for teachers focused on tailoring inquiry units to their classroom and facilitating science talk with their students, and to developing video and other resources to support teachers following the summer institute. Daily workshop activities will be video taped for subsequent review by the Curriculum Development team, Research and Internal Evaluator Carol Stuessy and C. Hemingway to inform both the curriculum and professional development activities. Video recordings will also be made of conversations among scientists and teachers and teachers manipulating science materials and mastering techniques. The aim is to post on the PlantingScience website video vignettes and how-to tutorials to support teacher and mentor roles in the online community.

New Modules Getting Underway for Field-testing this Fall.
"C-Ferns®: They do it in the open!" Spore Module – intended for students to progress from guided to open inquiry
Renee Lopez-Smith of Southern Illinois University will lead the science content development in collaboration with local Illinois teachers, whom she will identify through the SIU GK-12-supported project led by Dr. Karen Renzaglia. Renee is a GK-12 fellow in this program and connections to the secondary schools collaborating with it. Curriculum Coordinator Teresa Woods and Renee met in St. Louis in mid March to discuss inquiry guidelines, templates, and explore inquiry directions. Renee is in the process of testing out initial experiment ideas and contacting local teachers.

Working Big Ideas

- Diversity of plant life – not all plants are flowering plants
    - Comparison of C-Ferns® to angiosperms reveals evolutionary trends
- Basic aspects of plant reproduction are visible in C-Ferns®
    - Alternation of generations is visible – 2 free-living generations
        - The haploid (1n) gametophyte generation
        - The diploid (2n) sporophyte generation
- Environment affects plant growth and germination

"A Celery Bending Challenge" Physiology and Anatomy Module – intended as a fun challenge accessible to diverse students and easily modified to learners at different levels

Dr. Sundberg of Emporia State University originally developed this as an undergraduate biology laboratory investigation to address both osmosis and cell structure. Basic plant physiology and anatomy underlie student-directed questions regarding what causes bending in celery stalks.

For example, the figure illustrates celery segments from the same petiole all treated together in the same dish of tap water (different salt solutions can mimic these responses and get them to bend the other direction). Entry-level questions such as "What is the effect of the shape of the segment cut? How does "peeling" the celery affect bending?" engage students in experiential learning of plant anatomy. Depending on the learner level, students could generate hypotheses, design tests, and incorporate concepts ranging from osmosis, cell types, growth patterns, hormone effects, tensile strength, and vector physics. Dr. Sundberg initial tested this inquiry this semester with his undergraduate students. Based on its success as simple yet sophisticated inquiry adaptable to diverse learner levels, Dr. Sundberg has committed to developing this "invitation to inquiry" for PlantingScience. We anticipate that the "Celery Bending Challenge" will serve a similar student and teacher population as the "Corn Competition" that was alpha tested last year.

This summer T. Woods will seek to identify teachers to contribute to the writing of these new units, as well as teachers and scientist mentors to participate this fall and spring in small scale field-testing of the new units and larger scale field-testing of the genetics and pollination units.

III. PLANTINGSCIENCE PROGRESS OVERVIEW

To address the success of our program goals, we have developed a series of focus indicators regarding (1) scientific mentoring and discourse, (2) the use of plants as models to teach and learn science, and (3) the perceptions of participants' roles in the enterprise of science education. We are currently using pre- and post-tests to provide information on students' skills, science understanding, and attitudes. To assess short-term progress, we will use online surveys once implementation in classrooms is underway to gather information about teachers' facility and comfort using the open-ended plant inquiry materials. To gauge whether teachers are infusing the use of plants as model organisms for inquiry-based teaching in their classrooms, we will collect counts of the frequency of use of inquiry modules. To gather more in-depth understanding of the impact on teaching and learning, data will also be collected from on-site observations, written artifacts, and online discourse.

Please see May 2008 Annual Report for a complete table of Focus Indicators, including Project Outcome, Measurement and Scoring, and Data Collection. In the section that follows, most information provided will pertains to the project overall, including information on the 2008 summer institute teachers who worked with materials outlined in last year's annual report and recent field-testing classes described above.

Discourse and Mentoring Focus Indicators

How do plant scientists engage in scientific discourse with students and teachers? How do students engage in dialog with scientists and peers?

Patterns of discourse among the student team members, scientist mentors, and students from other research teams is summarized below. Counts of the length of dialogue are used to indicate the degree to which students are engaging in extended dialogues with scientists and peers and the degree to which plant scientists are mentoring students in inquiry planning, design, and implementation. Data collection is ongoing; preliminary results are given below.

Contributions to the conversation about student team projects are similar across the past two years. Student team members and the scientist mentor to which they are matched carry on the bulk of the conversation. Students from other teams occasionally comment, as do teachers of student teams, although participation in these categories depends highly on teacher's perspective and directions to student teams. Middle school students appear slightly more engaged in scientific discourse with their mentors than do high school students. Further analysis of dialog patterns is ongoing.

Table 1. *Patterns of contributions to dialog on student team research web pages*

Sessions	Posting Statistic	High School Team Web Pages			Middle School Team Web Pages		
		By Team Members	By Other Students	By Scientist Mentor	By Team Members	By Other Students	By Scientist Mentor
Fall 2007-Spring 2008	Average	7.9	2.8	5.3	10.2	2.6	5.7
	Maximum Number	32	7	24	58	21	29
Fall 2008 – Spring 2009	Average	7.1	1.8	4.6	10.7	2.5	6.3
	Maximum Number	64	19	20	75	20	18

Counts of the website Discussion Forum contributions serve as one measure of the degree to which plant scientists in the online community are mentoring teachers in inquiry planning, design, and implementation. Communication among teachers, mentors, and between scientists and teachers in the private Discussion Forum continues to grow. Hemingway continues to seed the Discussion Forums, with other individuals actively participating by starting threads and replying. Although most members of the online community participate as silent onlookers, the number of views clearly indicates. Barriers to participation in the Discussion Forum have not been systematically addressed yet, but lack of time is likely foremost. However, at least one teacher indicated via email a general unfamiliarity with posting on forums.

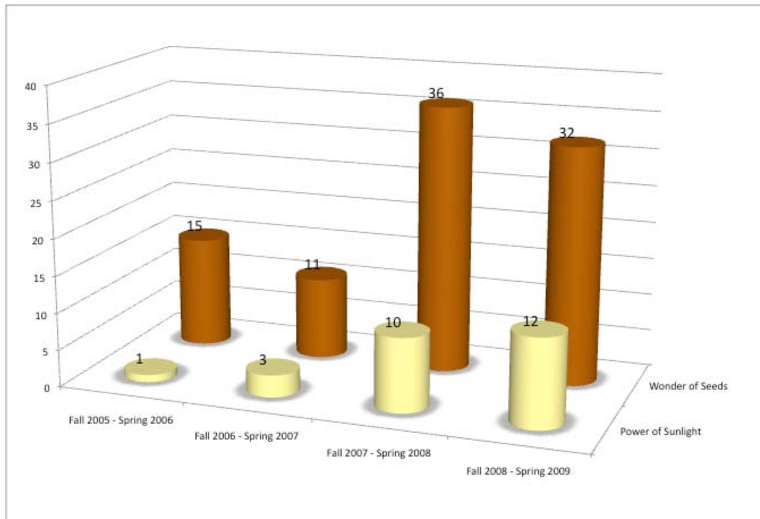
Table 2. *Active participation among online community to discussion forums*

Forum Category	Discussion Statistics	2008-2009 Academic Year	2007-2008 Academic Year Comparison
Mentor-Teacher	No. Threads Started	19	
	No. Replies Posted	38	
	No. Views	845	243 views
Teacher-Teacher	No. Threads Started	11	
	No. Replies Posted	21	
	No. Views	234	42 views
Mentor-Mentor	No. Threads Started	4	
	No. Replies Posted	25	
	No. Views	402	102 views

Observations of interactions between scientists and teachers and among teachers participating in the summer institute serve as another primary focus indicator of Scientific Mentoring. During the 2008 Summer Institute, Marshall Sundberg and Beverly Brown modeled collaborative and inquiry teaching. Teachers worked in teams of 2-3 to conduct open-ended investigations on photosynthesis, respiration, germination, or seedling growth. Teacher teams uploaded their projects onto a private clone of the PlantingScience website and received mentoring feedback from Dr. Sundberg and Brown, as well as peer-feedback from fellow teachers. Feedback in online postings and face-to-face conversations flowed continuously between scientists and teachers and among teacher teams during the five intensive days of science immersion.

Use of Plants as Model to Teach and Learn Science Focus Indicator.
How are teachers infusing the use of plants as models organisms for inquiry-based science teacher? How are teachers engaging in the development of technology-rich, web-based inquiry science materials?

Counts by module: The Wonder of Seeds continues to be the most used inquiry module, which is not surprising as it is accessible to diverse learner levels. The germination/seedling growth inquiry was chosen by 78.3% of classes in 2007 Academic year, and by 65.3% of classes this year. The Power of Sunlight (photosynthesis and respiration) module is geared for high school students, particularly well suited for AP biology, as it requires mastering techniques such as the leaf disc flotation. Early use of the Power of Sunlight module represents field-testing. Although numbers are not dramatic, the last two years have seen a couple of teachers who implement multiple modules either consecutively during one session with the same student group (usually Wonder of Seeds followed by the Power of Sunlight) or with different classes. Given that most online PlantingScience sessions last 3-5 weeks, these teachers are providing their students with remarkably extended opportunities for students to investigate biology content and learn how science works using plants as learning tools.



During the first Summer Institute for Teachers in August 2008, the participating teachers had extensive immersion experiences with both the Wonder of Seeds and Power of Sunlight modules. Despite equal exposure to both available modules, the Wonder of Seeds was selected 55% of time by the Summer Institute teachers and the Power of Sunlight implemented with 22% of Summer Institute Teacher classes. The remaining 22% of classes of Summer Institute teachers were selected to participate in field-testing.

Participation by teachers: This academic year saw three changes in teacher participation during the online mentored inquiry sessions: greater involvement of multiple classes from the same school; increases in field-testing teachers; and inclusion of teachers who had prior summer professional development experience. This spring, there were teacher pair sets at 3 schools (2 teachers each from Woodstock High School, GA, St. Andrews, TX, Marshall Middle School, WA).

Just under 8% of all students in the Spring 2009 session were students in field-testing classrooms (3 classes of genetics and 1 of pollination). Following the first Summer Institute for Teachers last August, all 13 (100%) participating Summer Institute teachers implemented PlantingScience inquiry modules and engaged their students in online mentored inquiry sessions. During the Fall 2008 session, 37.5% of the participating teachers (9 of 24) had been a part of the Summer Institute, and their students accounted for 31% of all students in the online session. In the Spring 2009 session, 24% of the teachers had summer professional development experience, and their students accounted for 16.5% of the students online. Four of the 13 (31%) teachers participated in both the fall and the spring online sessions. These four were the only teachers during the 2008-2009 year to engage in both sessions. Three of teachers (N. Volain, B. Simons-Water, and K. Vanderloop) were new to PlantingScience prior to the Summer Institute, while T. Lafferty engaged in both sessions last year and this year.

Are students developing good scientific questions about plants and designing methods for answering them? Are students demonstrating logical reasoning in their dialog? Are students developing abilities to work in teams to solve scientific problems? What are students posting to represent their work?

A combination of student work posted to the website, examination of student work submitted in teacher portfolios, and classroom observations conducted by C. Stuessy contribute to the overall data sets to address the above focus indicators. Data collection, particularly regarding the student thinking contained in the posts, is ongoing. Here, we present preliminary results concerning the broad brush of counts of types of student postings to their team web pages, and first contextualize these by describing the general student population.

Participation by students: Schools located in eastern, mid-west, and southern states predominate. Each dot on the map below indicates the participation of individual school, rather than the participation of individual teachers or classes.

High school students account for approximately 65% of the students currently served. Growth in the online learning community continues to be fueled primarily by increases in enrollment by our target population of high schools, with an average of 17 high school classes per session this year compared to 14.5 high school classes last academic year. Middle school numbers are holding steady around 7.5 schools per session this year compared to 6.5 last academic year.

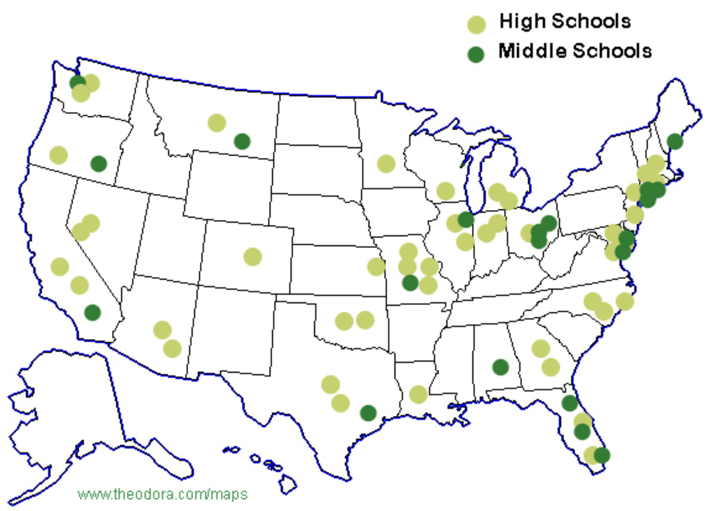


Table 3. General overview of student population in PlantingScience online community

Participation by Academic Year (Fall and Spring Online Sessions)	High School		Middle School	
	Number of Classes	Percent and no. Students	Number of Classes	Percent and no. Students
Fall 2005 - Spring 2006	3.5	45.4% n=235	2	11.6% n=60
Fall 2006 - Spring 2007	6	57.3 n=330	3	24.8 n=143
Fall 2007 - Spring 2008	14.5	58.9 n=726	6.5	28.6 n=352
Fall 2008 - Spring 2009	17	64.9 n=1430	7.7	33.7 n=742

High school and middle school student postings to team research web pages show some remarkably similar patterns. Teams of both student groups typically post research questions, predictions, and plans for a research design to answer the question posed. Students appear to get bogged down primarily in the presenting and making sense of the data phases.

Table 4. Patterns of types of student work posted on team research web page.

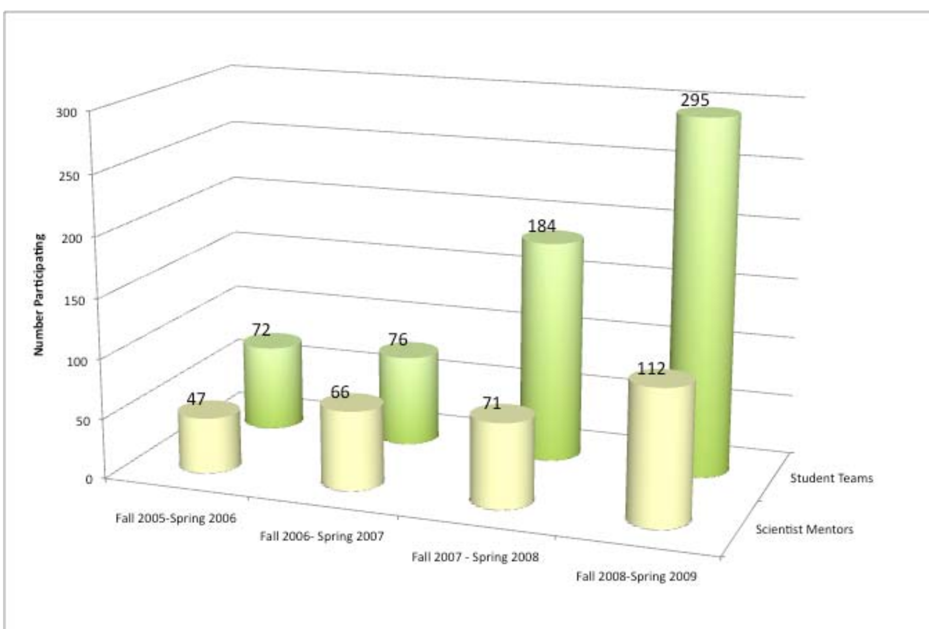
Team Postings	Research Question	Prediction	Research Design	Conclus-ion	Science Notebook	Data Sheets	Final Presentation	Images
High School Students								
Fall 2007 – Spring 2008 (321 teams)	87.8% (n=282)	81.9% (n=263)	74.1% (n=238)	42.9% (n=138)	43.9% (n=141)	25.5% (n=82)	15.3% (n=49)	31.8% (n=102)
Fall 2008 –	85.7%	79.2%	75.6%	53.7%	49.8%	29.3%	17.3%	34.3%

Spring 2009 (434 teams)	(n=372)	(n=344)	(n=328)	(n=233)	(n=216)	(n=127)	(n=75)	(n=149)
Middle School Students								
Fall 2007 – Spring 2008 (169 teams)	90.5% (n=153)	84.0% (n=142)	79.3% (n=134)	43.2% (n=73)	40.8% (n=69)	21.8% (n=37)	8.9% (n=15)	24.3% (n=41)
Fall 2008 – Spring 2009 (199 teams)	92.3% (n=185)	90.4% (n=180)	86.4% (n=172)	70.3% (n=140)	61.3% (n=122)	37.7% (n=75)	27.1% (n=54)	48.2% (n=96)

The percentage of student teams posting research conclusions has increased in the past year. Uploads of science notebooks and datasheets are also more common this year; however, they remain generally poorly represented as student postings. Dramatic increases during this academic year in middle school team postings of conclusions, notebooks, data sheets, and final presentations warrant additional investigation. Are these data an anomaly or is there something different about the set of middle school teachers and their students taking part this year? We suspect that the participation of several teachers highly proficient in inquiry teaching and integrating technology into the classroom underlie the dramatic rise in middle school postings this year, and will examine the data more closely to document patterns and identify influences.

In addition to documenting the percentage of teams posting particular types of information, we describe the patterns of posting with an eye toward answering how complete are the student projects. An ideal student team project would include, along with discourse in the blog, posts of a research question, prediction, research design, reflection on the findings and documentation of the research in the notebook or the data sheets. Approximately half of middle school student teams (54.3, n=108) and just over a third of high school student teams (38.7%, n=168) participating in the fall and spring sessions of the 2008-2009 academic year posted the full suite of elements for a "complete" project: questions, predictions, experimental designs, conclusions and supporting documentation the form of a science notebook and/or data sheets.

Participation by mentors:
Across the fall and spring online session offered during the 2008-2009 academic year, an average number of 112 scientists volunteered to mentor the 295 student teams posting their work and communicating online.



In addition to general increases in scientist participation, the Master Plant Science Team continues to grow steadily each year since the 9 inaugural members in 2006-2007. For the past two years, both the Botanical Society of America (BSA) and the American Society of Plant Biologists (ASPB) have sponsored graduate students (and some post-doctoral researchers in the case of BSA) to serve on this team of specially compensated and trained mentors. The Master Plant Science Team has risen to 25 members, up from 17 last year (a 47% increase).

Perceptions of Participant Roles in Science Enterprise Focus Indicator.
How do scientists perceive their roles as agents of change in science education? How do teachers perceive their roles as orchestrator of the learning environment? How do students perceive their abilities as individuals who can "do science"?

Mentor and teacher surveys are administered as links to Survey Monkey anonymous surveys. Mentors are surveyed at the end of an academic year, because most mentor in both sessions per year. Teachers are surveyed following each session.

Mentor survey highlights: The 2008-2009 mentor survey results include feedback from 123 mentors. Approximately 41% of the respondents have mentored in previous years, while 59% were new mentors this year. In keeping with results reported last year, the majority of mentors will mentor again (70.7% this year reported they will "definitely" mentor again, compared to 61% last year). Additional statistics compared across years also indicate some similarities in mentor experiences across years: 51.8% felt the students' abilities were lower than expected for the age group (57% in 2007-2008); 52.6% felt great satisfaction with the website (47.8% in 2007-2008); 40.4% indicated that participating as PlantingScience mentor elevated their interest and ability to support K-12 education (37.5% in 2007-2008); 39.1% indicated that the experience increased their motivation to mentor (41.7% in 2007-2008).

There were several shifts between years in mentor activities and perceptions: 54% of scientists spent 1-2 hours per week mentoring their student teams this year (where as 48% spent only 0-1 hours per week mentoring last year, it is important to note that in both years most scientists mentored 2 teams); 40.7% were satisfied to a great extent this year with project personnel communication (versus 66.7% satisfied to a great extent last year); 40.5% were not at all satisfied with classroom teacher communication this year (versus 56.5% not satisfied last year).

From open-ended responses in the online survey, we have selected several mentor comments.

I thoroughly enjoyed working as a mentor for 2 groups during this past session. One group experienced great success from the start, and they consistently reported their results in an easy-to-understand manner...they were a pleasure to work with and they kept me on my toes to ensure I was giving them proper guidance. The other group was equally as bright, yet they encountered problems with their experiment beyond their control. We worked through several situations, and after some tweaks, they succeeded. These students met adversity, worked through it, and won...is there any better example of teaching example?! —a mid-career scientist mentor

I love this stuff!! Actually, I think I was most impressed by the opportunity for these kids to have personal contact with a scientist. This may be the single most important element of this program. At the time I began my mentoring experience with Planting Science, I was also doing a unit in a non-biology majors class about the nature of science. Students wrote essays about their experiences and perceptions of science. So many of these perceptions were negative. I think Planting Science is an important step toward changing the public attitude toward science in our country. This is HUGELY IMPORTANT!!! —a pre-tenure scientist mentor

Communication needs to be clear and repeated so that everybody understands what is going on. Planting Science does a good job in helping with that communication, I wish my lab had an interactive domain like this website. In the future do you think Professors could set-up such a domain on this website? —a graduate student scientist mentor

Teacher survey highlights: Response rate was moderate for 2008 Fall Educator Survey (18 of 24 teachers) and high for 2009 Educator Survey (25 of 29 teachers). In keeping with results reported last year, the majority of participating teachers this year reported that their students' performance exceeded the learning objectives they planned for the inquiry (70.6% Fall 2008, 75% Spring 2009, compared to 67% Fall 2007, 90% Spring 2008).

Teachers were also asked "To what degree did the students meet YOUR expectations for carrying out the inquiry?" regarding specific inquiry skills, with possible responses: Much less than expected; Less than expected; More than expected; Much more than expected. Teacher responses fell primarily in the Less than or More than options, therefore percentages for only those responses are shown below. Teacher responses show interesting relationships to the percentages of types of student postings reported earlier.

Table 5. Percentage of teacher responses of less than or more than expected "To what degree did the students meet YOUR expectations for carrying out the inquiry?"

Teacher Responses	Asking a research question		Keeping a research journal		Recording quantitative and qualitative data		Critically thinking and communicating online	
	Fall '07 / Spring '08	Fall '08 / Spring '09	Fall '07 / Spring '08	Fall '08 / Spring '09	Fall '07 / Spring '08	Fall '08 / Spring '09	Fall '07 / Spring '08	Fall '08 / Spring '09
Less than expected	22% / 10%	12% / 18%	67% / 50%	65% / 48%	56% / 60%	41% / 37%	67% / 60%	29% / 21%
More than expected	78% / 80%	76% / 75%	22% / 30%	35% / 44%	33% / 40%	53% / 56%	33% / 10%	47% / 57%

There were slight shifts this year regarding how well teachers felt the PlantingScience design enabled their students to conduct scientific investigations, with fewer teachers reporting "very well" (61.1% Fall 2008, 46.4% Spring 2009, compared to 66.7% Fall 2007, 60.0% Spring 2008). To assess teacher's perceptions of their class's motivation and engagement in the experience conducting plant investigations in collaboration with plant scientists, we asked about teacher satisfaction about levels of student interest and student-mentor communication. Very few teachers indicated they were not at all or only satisfied to some extent; therefore Table 6 presents the percentage of teachers who reported moderate or great satisfaction.

Table 6. Extent of teacher satisfaction with the mentored inquiry experience in three areas.

Teacher Responses	Student interest in the experience		How frequently students responded to scientists		How frequently scientists responded to students	
	Fall '07 / Spring '08	Fall '08 / Spring '09	Fall '07 / Spring '08	Fall '08 / Spring '09	Fall '07 / Spring '08	Fall '08 / Spring '09
Moderate satisfaction	56% / 50%	41% / 39%	44% / 40%	53% / 50%	33% / 60%	53% / 50%
Great satisfaction	44% / 30%	47% / 46%	22% / 30%	23% / 29%	22% / 30%	35% / 36%

From open-ended responses in the online survey and postings in the Discussion Forum, we have selected several teacher comments.

I love this opportunity for kids. It is the best thing that I have to get kids interacting with a "community" of people trying to understand a small aspect of the world in a scientific way. It gets kids interested because they have choice in the question and design, they have opportunity to get their hands on stuff and use the computer to connect with people from around the country. How cool of a learning opportunity is that? —Anonymous teacher

Our school is new to plantingscience this year – and WE ARE LOVING IT!!! My kids have been really excited… Thanks to ALL of you for your time to help the kids! There are so many things that we simply cannot cover, and many of the comments…are so much more in-depth than what I can do. They are working in small groups, they are discussing and asking questions – which is GREST!!! I've seen that many have also logged in during non-school hours- Wow. —J. Forsyth, Woodstock High School

This is my second year with PS and again the students are amazed that they are communicating with an actual scientist (they thought I made up all of your names). —T. Johnson, Amundsen High School

Student survey highlights: Student pre-and post-tests are now administered online, using the Moodle learning management system integrated into the PlantingScience platform. The transition this academic year from pencil-and-paper to online pre-and post-tests had a few technological hiccups, with some students not being able to see the link to their online test. Paper pre-and post-tests are offered if teachers prefer. Using the Moodle system integrated through PlantingScience, teachers may log into their personalized teacher page and view student responses to the online tests in real time. We also provided Excel versions of the pre- and post-tests to teachers at the close of this spring session. As with the previous paper tests, we tailor the pre-and post-tests to reflect the teachers' specific learning objectives for the inquiry module they have chosen to implement. All pre-and post-tests also include a suite of standard attitudinal Likert-scale questions.

Analysis of pre- and post-tests is ongoing; therefore, selected anecdotal comments about what students liked most and least about the experience are provided below.

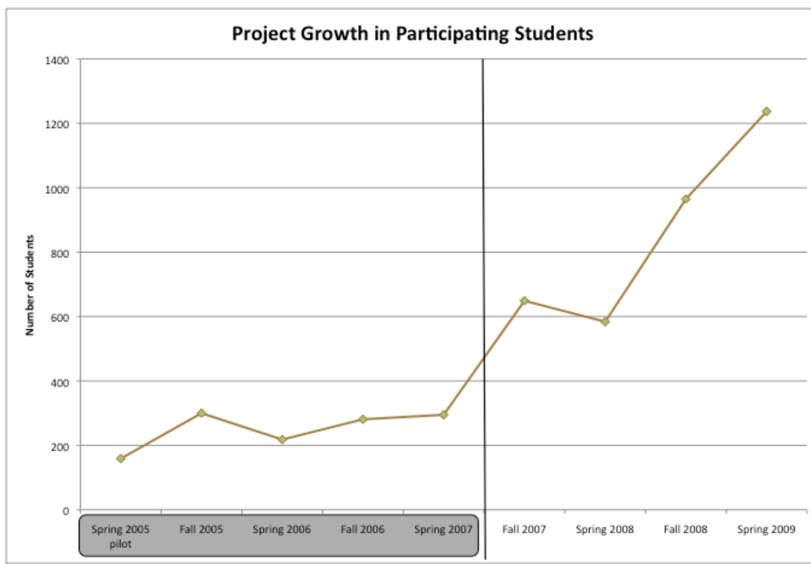
I liked that we could choose our way of doing any experiment we wanted. I did not enjoy the limits of time we had, because if we had more time, I think we could have done more and had better results. —Anonymous high school student

The thing I liked the most about the experiment is that you could send messages and receive messages from your mentor, a real scientist. The thing i liked least about this project is that we had a hard time measuring the seeds because they would always curve and twist. —Anonymous high school student

What I liked the best was seeing how the plants changed from last time we saw last time. My least was recording the results on excel. —Anonymous high school student

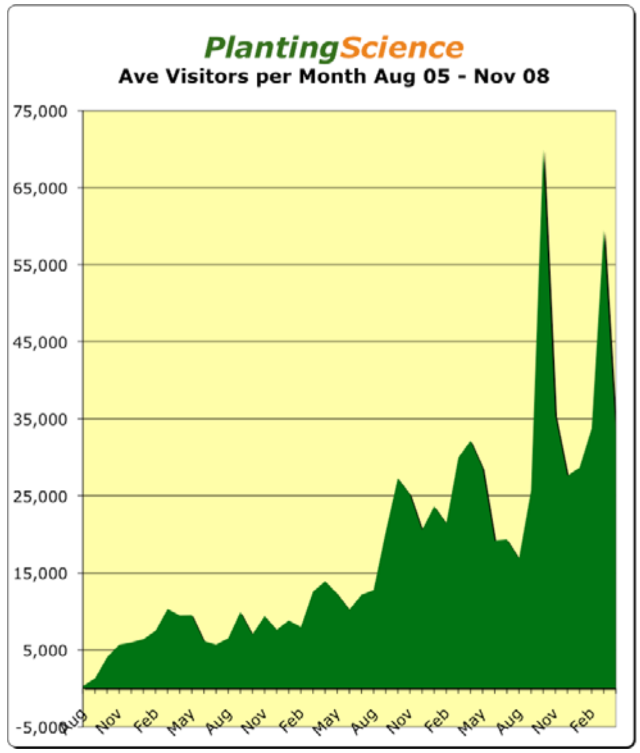
Additional Measurable Project Outcomes.

Growth: To date, PlantingScience has reached 4,688 students from 31 states across the nation working in 1,294 teams with online scientist mentors. The 2007 demarcation line indicates the onset of external funding for the project. The 2008-2009 academic year continued the sustained growth begun the previous year. While the number of participating school classes rose only 19% this year compared to last, the percent increase in number of students and student teams rose 78% and 60%, respectively.



Increases in scientist participation rose 59% from last year's level, which allowed the program to accommodate the student increases. Larger numbers of scientists were possible not only due to greater involvement by members of the Botanical Society of America, but also volunteers from additional societies and organizations (see relationship building below).

Relationship building: W. Dahl continues to actively partnerships with diverse Scientific Societies. Ten Scientific Societies, with a combined membership of over 250,000 scientists, are now involved in the program: **Botanical Society of America, American Society of Plant Biologists, American Society of Agronomy, American Society of Plant Taxonomists, American Fern Society, American Bryological and Lichenological Society, Society for Economic Botany, American Institute for Biological Sciences, Ecological Society of America, American Phytopathological Society,** and **4-H.** Scientists from these societies will be sought to contribute to new inquiry units, as well as volunteer to mentor in the program. At the Society board level, W. Dahl will promote the partnership and invite additional societies to establish sponsorships for graduate students to join the Master Plant Science Team.



Website activity: The website is widely accessed, with over 801,388 total visitors to date. Visitor sessions to the website are up this year to 349,806, compared with 183,949 visitors sessions during 2007. During the first 4 months of 2009, there have been 154,996 visitor sessions. Website activity, while it peaked during the official two-month window of opportunity during the fall and spring sessions, remained high throughout the academic year. This is, in part, due to the extended interactions of student teams and mentors beyond the official session closing dates. For example, many fall student teams continued posting into December and at least 3 schools in the spring session have continued in to May 2009. However, visits in August-September and Dec-Jan are presumably influenced by teachers exploring the internet.

IV. Expenditures

As of April 30, 2009, we have used $28,411.77. Funds are now being regularly disbursed to Curriculum Consultant T. Woods and the field-testing is coming to a close for 2 of the 3 modules field-tested this spring. we anticipate processing invoices for the materials costs, teacher and scientist stipends, and consultant fees for writing soon. We should exhaust all funds provided, $61,298 by January 1, 2010.

V. Closing Comments

On behalf of the Botanical Society of America and partner Societies in PlantingScience, we thank the Monsanto Fund for supporting the development of inquiry units that will provide students and their teachers with new opportunities to explore biology using plants as model organisms and experience how science works and scientific knowledge is built.

We thank you for your patience as the Curriculum Development Team settles into place. We trust you are receiving positive benefits and exposure as a PlantingScience funding partner.

Sincerely,

William Dahl, Executive Director, Botanical Society of America