Annual Report for Period: 09/2008 - 08/2009
Submitted on: 06/01/2009
Principal Investigator: Hemingway, Claire A.
Award ID: 0733280
Organization: Botanical Soc of America
Submitted By:
Hemingway, Claire - Principal Investigator
Title:
Planting Science Research in Education

Project Participants

Senior Personnel

Name: Hemingway, Claire
Worked for more than 160 Hours: Yes
Contribution to Project:

Dr. Claire Hemingway Principal Investigator
Dr. Hemingway has overseen direction and management of the program and coordinated communication and collaboration among stakeholders. She has managed website activities, recruited participants, engaged members of the Master Plant Science Team, other mentors, and teachers in online discussions, facilitated meetings, represented the project at national meetings, and coordinated new inquiry development, and trained project coordinator. Working closely with Dr. Stuessy, she has overseen the planning, recruitment, evaluation and dissemination of the summer professional development aspects of the Planting Science Education in Research project. Since submission of the First Annual Report and the Interim Report, Hemingway has been responsible for the following additional activities: (1) identified potential consultants to meet gaps in project and oversaw integration of consultant with project team and teachers and scientists taking part in curriculum writing and field testing, (2) indentified appropriate mentors in the project to contribute to field-testing with scientists and teachers, (3) communicated with potential collaborators, (4) managed the mentor-matches for the fall and spring sessions and continued training of Jennifer Potratz to handle additional PlantingScience management responsibilities (5) prepared and analyzed mentor and teacher online surveys, (6) analyzed project tracking data, (7) prepared Progress Report for project partners and communicated with education, and (8) identified and supported scientists and teachers to participate in teacher workshops and dissemination activities.

Name: Stuessy, Carol
Worked for more than 160 Hours: Yes
Contribution to Project:

Dr. Stuessy has managed the education research and internal evaluation component of the project. She has worked closely with Dr. Hemingway in organizing the summer professional development for the Fellows and disseminating information about the project. She trained of graduate students who will participate in education research activities during the summer and academic year classroom implementation (Cheryl Ann Peterson, Caroline Vasquez, Tori Hollas, Sara Spikes, Toni Ann Ivy). She has overseen collaborations to enhance recruitment efforts and local logistics to support the summer programs on the Texas A&M University campus.

Name: Dahl, William
Worked for more than 160 Hours: Yes
Contribution to Project:

William Dahl CoPrincipal Investigator
Mr. Dahl has overseen project administration. He has been very active building relationships with other science societies and organizations to expand the base of scientist mentors and the reach of the program. He has secured partners for the project from at least five new societies in the last year. He has negotiated a Memorandum of Understanding with 4-H.

Post-doc

Graduate Student

Undergraduate Student

Technician, Programmer

Name: Brandt, Rob

Worked for more than 160 Hours: Yes

Contribution to Project:

BSA IT Manager Rob Brandt has overseen computer programming and database management of the PlantingScience website. Since the last report, he has specifically (1) developed and implemented additional database queries to improve project tracking during and following online sessions, (2) led development of an electronic PlantingScience newsletter and archive for all newsletters, (3) developed an improved student registration system, (4) integrated Moodle online tests into the PlantingScience platform, (5) managed technical support for fall and spring online sessions, (6) contributed to team post-session reviews of fall and spring online sessions to determine future priorities, and (7) upgraded the PlantingScience platform to the latest version of Zikula.

Name: Potratz, Jennifer

Worked for more than 160 Hours: Yes

Contribution to Project:

Jennifer Potratz handled administrative responsibilities for student, teacher, and scientist registration in PlantingScience for the Fall 2008 and Spring 2009 online sessions and served as the primary contact for teachers and scientists. She learned to create tailored pre-and post-tests online. She has prepared and sent Certificates of Participation and supporting letters for administrators for both teachers and scientists. She has identified additional needs for maintaining project procedures and protocols, and improved systems for teacher and scientist registration. She has increased the pre-session telephone communication with teachers and is currently exploring technological tools to provide enhanced tutorials and teleconferencing opportunities for teachers and scientists. Jennifer is assisting with the Summer Institute by communicating with Summer Institute teachers, communicating and coordinating with personnel at Texas A & M University, and purchasing materials.

Other Participant

Name: Cacanindin, Heather

Worked for more than 160 Hours: No

Contribution to Project:

Name: Dickson, David

Worked for more than 160 Hours: No

Contribution to Project:

David Dickson, External Evaluator, has worked with Drs. Hemingway and Stuessy to establish a plan for formative and summative evaluation. Since the submission of the annual report and interim report, he and Hemingway have been in regular contact on general project progress and he and Stuessy have worked closely on evaluation progress. The Internal and External evaluator reports are integrated and provided in the supplemental data.

Research Experience for Undergraduates

Organizational Partners

American Society of Plant Biologists

At the time of the award, the American Society of Plant Biologists (ASPB) was the primary Scientific Society partner. Since the award, the ASPB increased commitment to the project by sponsoring five graduate student members of the Master Plant Science Team. The ASPB offers in-kind support in the form of free membership for the year?s mentoring service as well as 50% off meeting registration fees.

University of California, Berkeley

The PlantingScience project and the Botanical Society of America have become official partners in the Understanding Science project (NSF grant no. EAR 0624436). http://www.ucmp.berkeley.edu/understandingscience/index.php

Society for Economic Botany, Inc.

Contributing to recruitment of scientist mentors.

American Society of Agronomy

Contributing to recruitment of scientist mentors.

American Society of Plant Taxonomists

Contributing to recruitment of scientist mentors.

American Bryological and Lichenological

Contributing to recruitment of scientist mentors

American Fern Society

Contributing to recruitment of scientist mentors.

American Institute for Biological Scienc

Ecological Society of America

American Phytopathological Society

National 4-H Council

Other Collaborators or Contacts

The PlantingScience project continues to collaborate with Dr. Paul Williams of Wisconsin Fast Plants, Dr. Erin Dolan of the PREP (Partnership for Research and Education in Plants, supported by NIH Science Education Partnership Award SEPA and past NSF awards) and L. Griffing on the genetics unit in development.

We are initiating new collaborations on curricular materials with Dr. Karen Renzaglia?s GK12 fellow graduate student at Southern Illinois University, working on C-Fern- a classroom model that Karen helped establish.

The PlantingScience project and the Botanical Society of America have become official partners in the Understanding Science project (NSF grant no. EAR 0624436). http://www.ucmp.berkeley.edu/understandingscience/index.php

The Botanical Society of America is participating in COPUS http://www.copusproject.org/.

The PlantingScience project is beginning an exploratory pilot with 4-H to engage students and leaders of after-school science clubs in mentored inquiry projects.

The PlantingScience project is undertaking short-term consultant relationships with Sandra Honda, freelance science writer with extensive experience as a practicing plant biologist and science education specialist, and Teresa Woods, Ph.D candiate in Curriculum Instruction at Kansas State University, on the curriculum development aspects of the project.

Hemingway serves as an advisory member to the EOT committee of the iPlant Collaborative http://iplantcollaborative.org

Activities and Findings

Research and Education Activities:

Project Status and Context for 2009 Annual Report:
The Planting Science Research in Education project (DRK12 0733280) is in its second year of funding. We have supported four online mentored inquiry sessions, fall 2007, spring 2008, fall 2008, and spring 2009. We have hosted one summer teacher professional development workshop (August 2008) and are in final preparation stages for the second teacher workshop, which will take place June 8-16, 2009 in College Station, Texas. The narrative of the present report summarizes accomplishments, lessons learned, and project status with respect to goals and timeline. The supplemental data provided in attachments includes (1) Progress report for PlantingScience partners, (2) Annotated schedule of project progress, (3) supporting documents regarding training and development activities for teachers and scientists, including numbers impacted and examples of teacher? and scientists? reflections, and (4) the evaluation report, including interviews with 2008 workshop teachers and case studies with workshop teachers implanting during the following school year.

Project overview:
PlantingScience brings plant scientists into classrooms as online science mentors and creates new opportunities for students and teachers to learn how science works and how scientific research is conducted. Specific goals are to: bridge cultures of research and education, infuse classroom science with the excitement of scientific discovery, provide open-ended plant inquiry materials, and enhance understanding of science and increase students interest in and awareness of plants. The Botanical Society of America (BSA), the American Society of Plant Biologists (ASPB), in partnership with Texas A&M University and

K-12 teachers, are forging a nationwide science learning community (www.plantingscience.org). The project will deliver engaging instructional resources, with rich open-ended directions, that allow teachers to teach core biology standards in the context of doing science. Online mentors, communication, thinking, and formative assessment tools will scaffold student investigations. This project provides opportunities for teachers to implement standards-aligned, technology-supported inquiries during the school year, and to work with scientists and science educators in professional development workshops during the summer.

Major accomplishments in the second year:
We maintained the momentum established in the first year of the project in a successful summer professional development workshop and continued to support and evaluate classroom implementation of the growing online learning community. Notable accomplishments included:
- 100% implementation by 2008 summer workshop teachers during the school year
- trained project coordinator to handle administration of the online learning community and serve as primary contact for teachers and mentors
- supported substantial growth for the second consecutive year in student, teacher, and scientist participation in PlantingScience online learning community
- collected data on teaching and learning from teacher portfolios, classroom observations, on student work and dialog on website
- identified project needs for curriculum and web development and negotiated contracts to begin first steps to address these needs
- increased curriculum development activities and field tested two strands of the new Genetics module and a new Pollen module.
- significantly grew the network of scientific societies and organizations committed to partnering in the PlantingScience online learning community and to promoting secondary education reform
- enhanced integration of the research and education communities by engaging more plant scientists in secondary school education and teachers in authentic experiences in science and the scientific community

Meeting project goals for the second year:
Project Goal 1. Create opportunities for scientist mentors, students, and teachers to interact via advancing internet technologies.

We have met this goal through website improvements supporting administration automation features and greater facility of project coordinator handling the day-to-day running on the online learning community. In the second year of the project year, 2,002 students from high school and middle school classes collaborated with online scientist mentors. During the fall session, 104 scientists mentored student teams. During the Spring 2009 session, 120 scientists mentored student teams online. Partnerships in PlantingScience grew to eleven societies and organizations.

Project Goal 2. Provide students with authentic inquiry opportunities to learn about the process of science and to explore science concepts through hands-on plant investigations and public communication.

Approximately 430 high school student teams and 200 middle school teams have publically posted research projects online, and communicated with online scientists throughout the process. Teacher feedback indicates that the process of science is a primary student learning outcome of engaging in PlantingScience mentored online inquiries. Analysis of student postings indicates that students progress well through initial stages of posting research questions, predictions, and research plans, but tend to get bogged down when presenting and making sense of the data.

Project Goal 3. Develop and test inquiry teaching and learning resources that integrate plant science content and process and address National Science Education Standards.

The existing inquiry modules have served to escalate the prominence of plants in classrooms, as evidenced by the number of Wonder of Seeds and Power of Sunlight modules implemented in 53 classrooms in 48 schools. A new ?Corn Competition? inquiry unveiled at the 2008 summer institute has been implemented in a number of summer institute teacher classes. During the school year we made significant progress in developing additional inquiry modules. Two strands of the Genetic Module (one focusing on the plant research model species Arabidiopsis (with two classes) and the other focusing on the plant education model species Rapid cycling Brassica, also know as Wisconsin Fast Plants) and a new Pollen Module were drafted and field-tested. Field-tests included the participation of graduate students and post-doctoral researchers in the Master Plant Science Team to shadow student experiments while mentoring student teams. Writing and field-testing new modules this fall impacted two teachers, 75 students and one mentor. Writing and field-testing new modules this spring impacted four teachers, 93 students and eleven scientists. Two substantial improvements to the curricular material development were (1) the addition of consultants overseeing the curriculum development and integrating Understanding by Design framework and templates (2) the integration of Master Plant Science Team members in field-testing.

Project Goal 4. Provide teachers with materials and services to enhance their facility with scientific inquiry and plant biology.

We have met this goal by evaluating the 2008 teacher workshop and planning the second summer institute for teachers to be held this June 8-16. We will continue the successful shared leadership model and a sequence of summer professional development that begins with immersion in science content and process and follows with customized sessions on teaching and learning skills to support mentored inquiry experiences. Planning and recruitment for the 2009 workshop is complete. It will include 14 teachers, including 3 Teacher Leaders, 4 plant scientists who contributed to writing and field-testing of new inquiry modules, 2 curriculum developers, 4 Texas A&M graduate students, and project co-PIs.

Project Goal 5. Generate new understandings about collaborative learning environments that can be readily adapted for a number of scientific disciplines.

During the second year of the project we began meeting this project goal by collecting new sources of data to evaluate students? and teachers? interest in and understanding about how science is taught, learned, and done, including analysis of two classroom case studies and four teacher portfolios. We have also continued continuity with project tracking to following interactions among students, scientists, and teachers in the online community. This year there were substantial increases in interactions among scientists and teachers in the online discussion forum.

Findings: (See PDF version submitted by PI at the end of the report)

Major Achievements and Progress to Date to Meet Project Goals:
We continued to build on the demonstration model of a web-based communication platform. In the last year, we have further developed queries and programming tools that allow us to regularly assess the mentor, student, and teacher activities and interactions during an online session, and to extract data following a session on the types of information students post and communicate patterns among students, scientists and teachers. These website improvements supported the increased project growth that we experienced last year.

The 2008-2009 academic year continued the sustained growth. The number of participating school classes rose by 19% compared to last year, while the percent increase in number of students rose 78% and scientist participation rose 59% over last year?s level. Mentor recruitment efforts paid off significantly this year, both in terms of individual scientists registering to mentor and in terms of societies and organizations partnering with PlantingScience.

During the second year, the number of teachers and scientists engaging in PlantingScience activities beyond the online mentored inquiry session increased substantially, with scientists and teachers co-presenting at education meetings and engaged in curricular development activities. These close collaborations between teachers and scientists suggest that we are making progress toward building bridges between education and research communities and meeting broader impacts to sustain a national network that creates opportunities for students and teachers to participate in the practice of science and scientists to participate in K12 education.

Recruitment and planning for summer professional development session is on schedule and meeting our targets. We aimed to include teacher leaders, who have prior classroom experience with PlantingScience and can model inquiry teaching and learning to other participants. Three teacher leaders for the upcoming June session will be Allison Landry of Louisiana School for Math, Science, and the Arts, Toni Lafferty of C.H. Yoe High School, and Kathy Vanderloop of Appleton West High School.

MATERIALS DEVELOPMENT

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. It was originally envisioned that S. Honda would serve as Curriculum Writer, but her current work commitments do not permit this.

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.

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. Additional mentors not shadowing experiments: 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

Feedback from teacher V. McLean and mentor N. DeBoer on the pollen field-testing is provided in the Supplemental attachment.

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 Fall 2009 and Spring 2010.
?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.

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.

IMPACT

PlantingScience Online Learning Community.

To date, PlantingScience has reached 4,688 students from 31 states across the nation working in 1,294 teams with online scientist mentors. See 2009 report provided to partners for figures and tables illustrating the number of students, teachers, and scientists participating on a yearly basis and additional narrative about how involvement in the online learning community has impacted participants. (Supplemental Data, p. 3-18. II. Progress Report).

During the 2008-2009 academic year we held a fall and a spring online session as we have since 2006. The last academic year 2007-2008 marked the onset of external funding for the project. The present report will focus particularly on describing impacts over the second project year.

The fall 2008 session involved 24 teachers of 455 high school students and 287 middle school students working online with 104 scientist mentors. The spring 2009 session involved 29 teachers of 752 high school students and 667 middle school students working online with 120 scientist mentors. (See Supplemental Data tables III. A1. Teacher engagement p. 20 and III. B1. Scientist engagement p. 113.)

Significant increases in the number of students, teachers, and scientists impacted occurred in the second project 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. 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 members last year (a 47% increase). Relationship building among the plant and biology organizations has progressed well, reaching an unprecedented level of communication among like-minded organizations about working together to build a national network that supports building bridges between science research and science education.

The types of opportunities available to PlantingScience teachers and scientists have significantly increased since the first Annual Report, with the addition of teacher professional development activities, both in summer workshops and during the school year, and stepped-up activities related to curricular material development and co-hosted presentations at national science and science education meetings.

Thirteen teachers participated in the 2008 Summer Institute, along with two scientist presenters, science educators and project personnel and evaluators (See Supplemental Data p. 20 table III. A1. Teacher engagement). The 2008 Interim Report described the workshop participants and activities, and the Internal and External Evaluation section commented on the successful delivery. Summer Institute teachers were encouraged tailor implementation plans for their classrooms based on modules they experienced over the summer and they were provided time to complete template during the workshop (See Supplemental Data. P. 118 Evaluation Report, Part 1).

Teachers were also offered opportunities to engage in deeper refection of the teaching and learning that took place during their classroom implementation by providing narratives and artifacts in a Teaching Portfolio, working with a science education graduate student to videotape their classroom for a case study, participating in curriculum development and presenting at national meetings (See Supplemental Data table III. A1. Teacher engagement). Eight teachers originally indicated they would attempt to provide a portfolio (See Supplemental Data. Evaluation Report, Part 1). Thus far 3 portfolios have been received, another is expected next week, and two examples are provided in the Supplemental Data. The portfolio by K. Vanderloop was selected as an example because it is an incredibly comprehensive portfolio for the pilot genetics module, and is therefore of great value in informing us about module development as well as classroom implementation for the general PlantingScience model of online mentored inquiry collaborations among students, teachers, and scientists. Three teachers coordinated with Texas A&M University graduate students to observe classroom implementation of three days of the PlantingScience activities (most PlantingScience mentored inquiry projects last 2-4 weeks). Two case studies are provided in the Supplemental Data.

A cohort of PlantingScience teachers is emerging as project leaders, highly committed to the project and high committed to providing their students with authentic science experiences. These teachers have repeatedly responded enthusiastically to opportunities to become more engaged in the project, as workshop teacher leaders, co-writers and field testers of new modules, and presenters at meetings.

Eleven scientists took part in intensive curriculum development activities this year, five senior scientists writing modules and 6 young scientists (graduate students and post-doctoral researchers) shadowing experiments and mentoring student teams in field testing. (See Supplemental Data p. 113. table III. B1. Scientist engagement.)

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.

Impacts on student learning from the perspective of classroom teachers are provided in the Teacher Portfolios submitted by K. Vanderloop (Genetics) and R. Brewer (Wonder of Seeds) and the Field-testing feedback form submitted by V. McLean (Pollen), see Supplemental Data. Pp. 27-110. III A.3. Teacher Reflections and pp. 111-112. III. A.4. Teacher feedback. Mentors participating in field testing are also asked to reflect on student learning from their perspective, see Supplemental Data. Pp. 114-117. III. B. Mentor feedback.

Several common threads emerge regarding student learning and attitudes. One theme repeated in the attached supporting documents provided by the three teachers is the student gains in understanding the process of science. Another thread that re-appears, both in teacher?s comments and in student post-surveys when asked what like liked most and least about the experience, is the student excitement watching plants grow and the general lack of prior student understanding about plant requirements for life and growth.

From open-ended survey responses and postings in the Discussion Forum, we have selected several teacher comments illustrating additional common themes of collaborative learning benefits, particularly involving mentors.
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

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 these 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 (see Supplemental Data. P. 13. I. Progress Report, Table

4). 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. For example, 80-90% of middle school and high school teams this fall and spring posted a research prediction. Students appear to get bogged down primarily in the presenting and making sense of the data phases. For example, 40-60% posted science notebooks, and 9-27% posted final presentations.

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 in Supplemental Data. P. 9. I. Progress Report, Table 1. 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. 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.

Impacts on the community bridging education and research
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?

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 (Supplemental Data. P. 10. I. Progress Report, Table 2). Communication among teachers, mentors, and between scientists and teachers in the private Discussion Forum continues to grow, with 845 views in the Mentor-Teacher forum this year compared to 243 last year and 402 views in the Mentor-Mentor forum this year compared to 102 last year. 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.

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.

Impacts on scientists
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. Mentor survey highlights and selected quotes are below.

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).

From open-ended responses, 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

2009 Summer Institute Teachers.
We are in final preparation for the 2009 Summer Institute, which will be held June 8-16, 2009 at College Station, Texas. As the workshop has not yet been delivered, we report here on recruitment and demographic data on teachers accepted. Our target number of teachers for the 2009 workshop, as with the 2008 workshop, was 16 teachers. We accepted 18 teachers from 11 states: Arizona (2), California, Georgia, Michigan, Kansas (2), Maryland, Missouri, Louisiana (2), Pennsylvania, Texas (4), and Wisconsin. These teachers are responsible for students in grades 7 to 12, with 6 teachers responsible for teaching grades 9-12, and 3 teaching grades 10-12. Teaching experience ranges from 3 years to 25 years: in the classroom 1-4 years, 1 teacher; 5-8 years, 9 teachers, 9-15 years, 2 teacher, 16-20 years, 2 teachers; >20 years, 3 teachers.

Four teachers are returning for a second consecutive workshop year. Five teachers have prior experience participating on PlantingScience online mentored inquiry experiences. Last year, only three participants were familiar with the goals and activities of the project prior to arriving for the workshop. Two teachers have prior experience with a companion plant-related workshop offered at Texas A&M University (my Plant IT). This combination of experiences among this year?s participants is highly encouraging.

Four of the accepted teachers subsequently declined. Two cited schedule conflicts with family obligations had arisen, a common issue for workshop number loss. The other two cases indicated different kinds of pressures: competition among plant-related opportunities and difficulties in this period of economic duress. One teacher from Houston was accepted as an iPlant Fellow and chose that opportunity; one from California was made redundant at the close of this school year due to budget cuts.

RECRUITMENT AND RETENTION

Teacher recruitment and retention processes are not substantially changed from original plans. To advertise to teachers nationally, we posted information on the National Association of Biology Teachers (NABT) and National Science Teachers Association (NSTA) websites beginning in January. We also presented and hosted exhibit booths at both of these education meetings. Letters of invitation also were sent directly to K-12 members of the Botanical Society of America and past project participants. Application forms and program brochures were available for download from www.PlantingScience.org and the Botanical Society of America. Application forms and program brochures were handed out to teachers who came by the Botanical Society of America booth and the American Society of Plant Biologists booth at the NABT and NSTA meetings.

One factor that we believe is helpful regarding teacher retention is offering opportunities for professional growth within the project. Toni Lafferty and Valdine McLean, who are exceptionally experienced, nationally recognized teacher leaders, are both/have both been involved in curriculum development and presentation activities. In personal conversations these teachers have relayed that such additional opportunities are immensely valuable to them personally, maintaining their intellectual curiosity and growth. For teachers in the ?highly engaged cohort? who are earlier in their teaching careers, such as Kathy Vanderloop and Allison Landry who have been teaching less than a decade, these additional project opportunities are important to building their professional lives. Prior to co-hosting the March NSTA meeting, Allison Landry had not previously attended a national education meeting.

Recruitment procedures for mentors have been driven primarily through the partner Scientific Societies. Posters and workshops at the BSA and ASPB meetings are additional means of recruiting new mentors (see Outreach section). One small change to recruiting mentors from within the BSA membership this year was the addition of a PlantingScience participation check box on the Membership Join/Renew form. A recent partner, the American Phytopathalogical Society, has promoted PlantingScience to their membership through links on the APS Facebook page.

Community building continues at the board level among societies and other like-minded organizations. Dahl has spoken about the project to a wide array of groups including Horticultural Society of America, Soil Science Society of America, Crop Science Society of America, Mycological Society of America, Phytochemical Society of North America, and USDA/ARS.

EVALUATION ACTIVITIES

During the school year following the 2008 Summer Institute, Co-PI and Internal Evaluator Carol Stuessy oversaw the education research and internal evaluation components of the project, and maintained close communication with External Evaluator. Hemingway independently scheduled conversations with the External Evaluator every few months and provided key updates of activities and documents.
The Internal and External Evaluators introduce their current Report provided in the Supplemental Data (pp. 118-156) as follows:

This document represents a collaborative effort between external and internal evaluators with detailed input from graduate student researchers/mentors who were engaged to work with management team members and teachers during the first year?s offering of the NSF-sponsored PlantingScience workshop. While high school teachers were the focus of planned workshop activities, the inclusion of doctoral-level graduate students in science education as researchers, mentors, and co-evaluators has been an additional, albeit unpredicted, broader impact of the project. The various roles these individuals have played in the implementation of the PlantingScience project have resulted in their development of new conceptions about what it means to be actors in providing professional development within a complex setting, such as that provided by PlantingScience. Graduate students have had experiences in the completion of tasks associated with planning, implementing, reviewing, and revising parts of a complex project that have involved both in-site and off-site consultants, trainers, and project management team members that include scientists, science educators, and professional training teams.

The structure of this document represents the contributions of graduate students to the evaluation component of the first year of PlantingScience. While Tori Hollas, Cheryl Ann Peterson, Laura Ruebush, and Sara Spikes provided continuity from summer workshop through teacher-participants? school year implementations, we were also fortunate to have Toni Ivey, Ra?sheedah Richardson, and Caroline Vasquez join the summer graduate team to engage in daily workshop activities and formative evaluations, as well as perform duties associated with teacher transportation back and forth to the hotel and periodic visits to local eateries and variety stores. As well, these additional graduate students contributed to data collection during the summer workshop.

Internal and external evaluators directed the activities of the three permanent graduate students on the research and evaluation team: Cheryl Ann Peterson, Laura Ruebush, and Sara Spikes. These graduate students managed and manipulated data, traveled to observe classrooms, conducted preliminary analyses of data, and wrote many sections of this report in first-draft form. As co-researchers and co-evaluators, their names are included as co-authors of this document with the internal and external evaluators.

As co-directors of the evaluation component of the PlantingScience project, we acknowledge the extraordinary contributions of the graduate student evaluation team members in collecting, organizing, and analyzing data for this report.

Carol L. Stuessy, Internal Evaluator
David H. Dickson, External Evaluator

ADDITIONAL SUPPORT

An initial two-year grant was provided by the Monsanto Fund to jump-start the curriculum development. The Monsanto Fund partnership is to support initial inquiry-writing retreats and provide starter materials for field-testing classrooms. The second year report has recently been submitted, and will seek to continue this partnership beyond the initial two-years of funding.

PROJECT SCHEDULE, CHANGES, CHALLENGES, AND SOLUTIONS

The majority of project activities are on schedule (see Supplemental Data. P. 19. II. Annotated Schedule Timeline). Delivery of Year 1 Summer Workshops, implementation of school year online mentored inquiry sessions and classroom observations of module implementations, and dissemination of project are all on schedule.

A potentially limiting factor to the project (securing commitment from scientists to serve as online mentors) is gratefully ahead of schedule. We believe this progress is possible because scientists and society boards personally recognize the great needs of education reform and they feel there is power in collaborative efforts harnessing innovative social networking technologies.

Certain aspects of the development and integration of new web tools and resources are ahead of schedule, including the development of sophisticated queries for project tracking and a revised student registration system to accommodate greater student numbers while maintaining security measures.

Project activities that are behind schedule relate primarily to curricular materials development and website user interface improvements, including how students, teachers, and scientists access and engage with the online curricular materials. This academic year we began administering student pre-and post-tests 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. Certain aspects of module evaluation, such as analysis of pre-and post-tests and students? online dialog, are behind schedule, but are not yet causing significant difficulty for overall project progress.

A root cause to the challenges we encountered keeping to our planned timeline of curricular materials development and website user interface improvements was the underestimation of the time and expertise needed to support these activities. Last year Hemingway attempted to manage all the curriculum development activities as well as overseeing the online sessions, summer professional development activities, and dissemination activities, which did not leave sufficient time for curriculum development and evaluation. To overcome this problem, we intent to pursue additional funding support to cover outside consultants in curriculum and web development. Thus far we have made partial progress in short-term contracts with consultants to support the curriculum coordination and writing. We will seek additional funds to continue this curriculum development work and also identify a web developer consultant to integrate new curricular materials into the PlantingScience online platform.

One project change in exploratory phase is the extension of PlantingScience into after school science clubs. In March, 2009 William Dahl pursued a Memorandum of Understanding with the National 4-H Headquarters, Cooperative State Research, Education and Extension Service, U.S. Department of Agriculture (4-H) to explore the use of PlantingScience with 4-H Clubs.

Training and Development:

OPPORTUNITIES FOR TRAINING AND DEVELOPMENT

Teachers and Scientists at Summer Workshop. The model for teacher professional development workshops has not changed from last year?s successful session. See Supplemental Data III. A2 for the daily schedule At-a-Glance provided to teachers (p. 22) and the working schedule collaboratively developed by the scientist presenters and project team (p. 23-26) to coordinate activities and identify logistic needs. The first five days will be devoted to science immersion experiences in which teachers collaborate with scientists, fellow teachers, and project team to explore the biology content underpinning the inquiry modules and master techniques for successful team experiments. During this week working in small teams, teachers also become familiar with the PlantingScience website by posting their team?s data to team webpages set up on a teacher workspace (a clone of the regular website, so that the look and feel of the web is identical, but the teachers? work is private). Time is set aside for daily cross-talk among teams and large group conversations about insights and questions that have arisen during the day?s activities. The second phase of the workshop will provide extended opportunities for teachers to focus more specifically on the teaching and learning skills that support classroom implementation of mentored inquiry projects, such as facilitating classroom dialog and online conversations with mentors, establishing an inquiry environment, and customized sessions on working with Excel and other topics selected by participants.

Graduate students and post-doctoral members of the Master Plant Science Team. Directly and intensively engaging selected graduate students and post-doctoral researchers from the PlantingScience Master Plant Science team (MPST) in curricular module field testing is proving to be invaluable new improvement, this year 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. The MPST is a pool of self-selected young scientists with a strong interest in mentoring secondary school students, and several individuals are GK12 fellows or have other experience working in school settings. The participation of MPST members in field-testing PlantingScience modules provides opportunities for these young students to either be exposed to or build upon their understanding of theoretical frameworks of inquiry-based learning, sound curriculum development. For example, MPST member Brunie Burgos, who shadowed student experiments and mentored teams during the fall field test of the Rapid Cycling Brassica Genetics strand, had an interest in generally increasing her involvement in secondary school education. MPST member Nick DeBoer, who shadowed student experiments and mentored teams during the spring field test of the Pollen Module, is a GK12 fellow and had an interest in expanding his curriculum and assessment experience. Brunie?s and Nick?s perspectives on the field-testing are provided in the Supplemental Data III. B.2 pp. 114-117.

An unexpected, but much welcomed, outcome of engaging the MPST in field-testing is that 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.

Texas A&M University Graduate Students. During regular meetings, Stuessy has been providing ongoing training for the Texas A&M University students who have and will participate in the summer programming for teachers and in the education research components, conducting classroom case studies, and analyzing teaching and learning artifacts including the online dialogs.

Botanical Society of America Project Coordinator. Hemingway has spent extensive time this year training Jennifer Potratz, who was hired as project coordinator just prior to last summer?s teacher workshop. BSA IT Manager Rob Brandt assisted in the training procedures, particularly regarding administration of the PostNuke online platform.

Outreach Activities:

November 2008. National Association of Biology Teachers (NABT) Meeting. Memphis, TN Hemingway and PlantingScience mentor Jan Barber presented a session. NABT past-president Toby Horn and NSF Program Officer David Hanych attended the session. The Botanical Society of America, supported by Project Coordinator Jennifer Potratz, hosted a booth and distributed project flyers.

November 2008. School Science and Mathematics Association Meeting. Durham, NC
Stuessy and TAMU graduate student Peterson workshop.

November 2008. National Science Teachers Association. Regional. Portland, OR
Hemingway and C. Packard (a successful middle school teacher in the program) presented a hands-on workshop. Two teachers attending this workshop, participated in the Spring 2009 session.
December 2008. Council of Scientific Society Presidents Meeting. William Dahl spoke to a number of Presidents and Executive Directors about PlantingScience.

March 2009. National Science Teachers Association (NSTA) Meeting. New Orleans, LA
?Making meaning of science investigations with online PlantingScience mentors?. Hemingway, with mentor Margaret Conover, teachers Allison Landry and Toni Lafferty, also attended by project coordinator J. Potratz and PlantingScience collaborator Ethel Stanley.

March 23, 2009. William Dahl gave a presentation on PlantingScience at the American Phytopathelogical Society?s ?Future of Education? workshop.

March 2009. William Dahl pursued a Memorandum of Understanding with the National 4-H Headquarters, Cooperative State Research, Education and Extension Service, U.S. Department of Agriculture (4-H) to explore the use of PlantingScience with 4-H Clubs.

July 6-17, 2009. Plant IT Careers, Cases, and Collaboration Summer Institute for Teachers and Students. College Station, TX.
Hemingway, Stuessy, and collaborator Stanely are co-PIs on an NSF ITEST project, which serves as a companion to PlantingScience.

July 25-29, 2009. Botany and Mycology 2009. Snowbird, UT.
PlantingScience Informal Mixer for Mentors and Project Team.

Journal Publications

Hemingway, C, "Education News and Notes", Plant Science Bulletin, p. 102, vol. 54, (2008). Published,

Musante, S., "The 2008 Biology Education Summit. Special Report.", BioScience, p. 685, vol. 58, (2008). Published,

Hemingway, C, "Education News and Notes", Plant Science Bulletin, p. 6-8, vol. 55, (2009). Published,

Hemingway, C, "Education News and Notes", Plant Science Bulletin, p. , vol. 55(2), (2009). Published,

Books or Other One-time Publications

Web/Internet Site

URL(s):
www.plantingscience.org
Description:
Student products added to the website this year include the 434 high school student team projects and 199 middle school team projects in the Research Gallery, a searchable digital

legacy of all student projects.

PlantingScience Newsletters are sent to session participants and archived on the website.
http://www.plantingscience.org/index.php?module=pagesetter&tid=18

Other Specific Products

Contributions

Contributions within Discipline:

A major contribution within the discipline is the establishment of a network including 11 society partners.

Contributions to Other Disciplines:

Contributions to Human Resource Development:

Contributions to Resources for Research and Education:

Contributions Beyond Science and Engineering:

Conference Proceedings

Special Requirements

Special reporting requirements:

Although we have not made changes to the scope of the project, we are slightly behind our desired schedule, primarily in website development and planning for the next series of inquiry modules to be developed, and have significant carry-over of funds. The carry-over for funds is partly due to the timing of our summer program and the fact that major financial outlay for the participant costs has yet to be spent.

Change in Objectives or Scope: None

Animal, Human Subjects, Biohazards: None

Categories for which nothing is reported:

Any Book

Any Product

Contributions: To Any Other Disciplines

Contributions: To Any Human Resource Development

Contributions: To Any Resources for Research and Education

Contributions: To Any Beyond Science and Engineering

Any Conference

PlantingScience Interim Report Supporting Attachments

1. Images of Summer Professional Development Session held August 4-13, 2008 at Texas A&M University.

2. Interim Internal Evaluation Report

3. External Evaluation Report

1. L to R. Scientist M. Sundberg advising on experimental set up. Teacher Leader T. Lafferty works with colleague. Teacher Leader A. Landry with fellow teacher N. Voalin and graduate student T. Ivey.

L to R. Learning a leaf disk filtration technique. Collecting data on team experiment.

L to R. Learning time-lapse photography. Collecting samples in the greenhouse.

2. Internal Interim Report

Planting Science

September 24, 2008

Carol L. Stuessy, Co-Principal Investigator
Site Coordination, Research and Internal Evaluation Team

Seven graduate students joined the Texas A&M team to assist with Research, Evaluation, and Site Coordination for the first summer workshop of the PlantingScience Project, which occurred 2 weeks in August. The number of graduate students was increased from 4 to 7 for the first summer for a number of reasons, which included the complexity of the project, the need to run an excellent pilot project before full implementation in the second and third summers, additional funding due to delayed contract start date, and the availability of expertise provided by graduate students who themselves had been high school science teachers.

Site Coordination

An off-campus hotel was used to house the training personnel and teacher-participants for the two weeks of the summer workshop. The hotel was not close enough to allow participants to walk to the training site. Breakfast was served each morning at the hotel. Teachers exercised options to go out for lunch or to order lunch in, depending on the weather. Lunch options were coordinated by graduate students for both weeks of the workshop. Teachers chose sites off campus for dinner.

Teachers received stipends on the last day of the workshop before they returned to their home states. Their reimbursements for meals were sent to them after they left the workshop and required receipts delivered to Site Coordinator. Ms. Tori Hollas in College Station and Ms. Jennifer Potratz in St. Louis sorted out budget and roles and responsibilities regarding participants as the workshop progressed, and site coordination responsibilities were met with little disruption to participants or project management personnel.

The location of the hotel was less than desirable and plans are being made to find a dormitory on campus to ease transportation issues that emerged with the hotel being so far away from campus. Plans are also being made to change the month of the workshop from August to June to avoid issues associated with students returning to campus for the fall semester.

Research Efforts

Table 1 lists the several types of data (surveys, interviews, interview field notes, daily concern forms, written case assessments, and observations) collected during the two-week workshop. The survey instruments included the CBAT, M-BPS, and STEBI. All the teachers filled out the survey instruments and we have copies of each of these

Table 1.
Data collected during Planting Science Summer 1 workshop.

Instrument- Planting Science	
Application Form	complete
CBAT- Survey	complete
CLES- Pre- Survey	complete
CLES- Post- Survey	complete
M-BPS- Survey	complete
STEBI- Survey	complete
Technology Use Survey	complete
Pre-Technology Interview	missing 2 of 13
Pre-Technology Interview Field Notes	complete
Barriers to Implementation Interview	complete
Barriers to Implementation Field Notes	complete
Post Technology Interview	complete
Post Technology Interview Field Notes	complete
Implementation Plans	complete
Program Observations- Planting Science	
Teacher Observations	missing 4 of 6
Daily Data Collection Items- Planting Science	
Daily Concerns	complete
Sign In Sheets	complete
Video Tape	complete
Other Items- Planting Science	
Exit Audio Discussion	complete

surveys. The interviews included Pre- Technology, Post- Technology, Barriers to Implementation, Group, and Case Assessment. All interviews along with the field notes taken by the interviewer are accounted for. Teachers were required to fill out written case assessment sheets and all assessments were completed. Graduate students from the research and evaluation team wrote down their teacher observations during the summer session. All graduate students took notes but only two of the six have turned in typed copies of their notes. An audio recording was made of the final exit discussion between teachers and Dr. Stuessy.

Overall, all forms of the raw data are accounted for with the exception of the Graduate Student teacher observations and audio recordings of two teacher's Pre-Technology interviews. Three of the interviews have been transcribed and the rest of the interviews will be sent to transcribers this month. An audio transcription log is being created to record what interviews have been transcribed. Teacher profiles were created using the survey instruments and some of the interview questions.

Overall, all forms of the raw data are accounted for with the exception of the Graduate Student teacher and student observations. Three of the interviews have been transcribed and the rest of the interviews are currently being sent to transcribers. These transcriptions should be complete by the end of October. An audio transcription log is being created to record what interviews have been transcribed. Teacher profiles of entry characteristics were created using the survey instruments and some of the interview questions.

Internal Evaluation

Daily concerns forms were passed out to teachers each day with the exception of the final workshop day. Not every teacher filled out a form each day as participation was voluntary. All forms for each day are on file. These forms were used to assess levels of teachers' concerns on a daily basis. Internal Evaluation Team meetings were held every afternoon after the completion of the day's activities and included the graduate students, Dr. Hemingway and Dr. Stuessy, and the two workshop presenters during the first week.

Overall, these meetings revealed a well-run workshop with all members of the project team cooperating to address participant-teachers' needs, which were minimal. Participant-teachers' daily reflections indicated high levels of satisfaction with all activities during the two weeks of the PlantingScience workshop.

Summary

Site coordination and formative evaluation strategies will be maintained for next summer's workshop. Research data are in various stages of processing, with analysis occurring during the 2008-2009 school year. More immediate plans have turned to classroom visits of 3 PlantingScience teachers during the school year. Tentatively, visits will be made to Ms Toni Laffterty in Texas; Ms. Lisa Thomson in Georgia; and Mr. Michael Hotes in Kansas. In each case, a graduate student will observe three days of classroom instruction in which BioQuest materials are being implemented. The MSCOPS (Mathematics and Science Classroom Observation Protocol System) will be used to describe the classroom in terms of student-directedness and complexity of instruction. Follow-up interviews will be conducted after the first two days of observation. These observations will lead to critical information about the effects of the workshop on classroom implementation.

3. External Evaluator Report

External Evaluation Report for Year One

of

Planting Science Education Research in Education

NSF Grant DRL 0733280
BSA Task 02-TX-0733280

Prepared for:
Claire Hemmingway
Education Director
Botanical Society of America

by

David H. Dickson
Senior Scientist
South Texas Sciences

September 2008

Objectives of DRK-12 Planting Science Workshop

The objectives of this project are: (1) Create opportunities for scientist, students, and teachers to interact via advancing internet technology; (2) Provide students with authentic inquiry opportunities to learn about the process of science and to explore science concepts through hands-on plant investigations and public communication; (3) Develop and test inquiry teaching and learning resources that integrate plant science content and process and address National Science Education Standards; (4) Generate new understanding about collaborative learning environments that can be readily adapted for a number of scientific disciplines.

Organization

The DRK-12 PlantingScience Presentation Team (Dr. Hemingway, P.I.; Dr. Sundberg, Dr. Brown, and Dr. Stuessy) planned, developed, and executed a schedule that provided flexibility and stability that met teacher-participants' needs for structure in providing: (1) technical content, (2) experiences, (3) time for discussion, (4) opportunities to use hands-on materials, and (5) reflection.

General Schedule Format and Description

Each morning, participants were called together at 8:30 with brief "housekeeping" issues regarding technology, transportation, and other personal needs. Two 1¼ hour sessions were provided in the morning with a 15-minute break scheduled between sessions. An hour and a half provided ample time for lunch to walk from the workshop location to local restaurants. In the afternoon, the same format was followed. Closure and reflection began at 4:00 to provide ample time for daily reflection sheets to be filled out by teacher-participants, closing remarks by presenters, and additional information about evening plans.

Immediately after teacher- participants left for their hotels, the entire presentation team and graduate students met for a daily debriefing. Teacher-participants' daily reflection sheets were reviewed and discussed.

Schedule Template

8:30-8:40	Housekeeping
8:40-10:00	Session I
10:00-10:15	Break
10:15-11:30	Session II
11:30-12:45	Lunch
12:45-2:00	Session III
2:00-2:15	Break
2:15-4:00	Session IV
4:00-5:00	Reflection and Closure
5:00-6:00	Daily Debrief – Presentation Team

Hands-On Scientific Inquiry with Scientists –Week One

During the first 5 days of the workshop, scientists Dr. Sundberg and Dr. Brown modeled inquiry lessons on seed germination, respiration, and photosynthesis. Technical content and pedagogy discussions led by the scientists were brief and focused on a range of teacher-participants' hands-on laboratory experiences. Teacher- participants became familiar with laboratory equipment and procedures as they developed planting science scientific inquiries appropriate for high school classes. Groups rotated by day (as per teacher-participants' suggestions on daily concerns sheets) to enable better discussion and exposure to other teachers' methods and ideas for classroom implementation.

Transition with Principal Investigators – Saturday

On Saturday morning, Dr. Hemingway and Dr. Stuessy led a transition discussion about classroom implementation. Dr. Hemingway presented a contemporary real world model of science that reflected the more typical recursive process of science as well as the components of peer review by the scientific community and implications for society. After a break, Dr. Stuessy solicited input from teacher-participants regarding their ideas about the format for a teacher portfolio for teachers to document their implementation of the PlantingScience activities in their classroom. Participants were dismissed at lunch to work on their own for the rest of Saturday and Sunday.
Teacher reflection sheets on the morning's activities noted that teachers were ready to talk about transition of inquiry experiences into the classroom and that they were quite pleased with the morning experiences.

Customized Options – Week Two

On Monday and Tuesday, small-group options were provided for each of the session time slots so that participants might choose their topics for discussion and new information. Each session was structured to provide opportunities for participants to ask questions, describe their own classroom practices, and engage in discussion with others. Topics were chosen to provide information and skills that would promote teachers' abilities to implement the PlantingScience scientific mentoring model in their own classrooms. These topics ranged from computer sessions on software (e.g., Excel, Inspiration), discussions about motivation of second-language learners, how to talk on-line with scientists, new models of classroom inquiry, assessment, group work, and use of laboratory notebooks. Prior to the workshop, teachers had indicated their preferences on a checklist of sessions they would like to attend. Presenters included Dr. Hemingway and Dr. Stuessy, master teacher Toni Lafferty, and graduate students. Teacher reflection sheets on these days noted that teachers were very pleased with the opportunities to talk about what they wanted to talk about, but still wanted more opportunities to hear from each other.

On Wednesday, the first session included a computer-based orientation to many of the features available to teachers and students on the PlantingScience website. Dr. Hemingway guided teachers as they navigated the site and answered questions as they came up in this session. Dr. Hemingway also noted special requests that teachers made regarding features that would assist them in using the site, which she said she would relay to the programmer. The purpose of the second session was to provide teachers with time to discuss and review the essential features of the implementation: use of laboratory journals, communication with scientists, assessing student work, use of inquiry materials, and integration with existing curricular content. In the jigsaw, small "home-team" groups of 3-4 individuals reviewed information regarding a list of 9 questions about implementation to solicit numerous ideas about how one might approach evaluation of journal entries, for instance. After a 40-minute time period in home team, these groups disbanded to form presentation groups, composed of one member from each home team group. Presentation groups consolidated information from each of the home teams and planned methods for answering each of three questions (of the original list of 9) to which they were assigned. Presentation groups had 25 minutes to prepare their responses and assign them to members of their group. Short presentations (maximum of 5 minutes each) were then heard by the entire group of teachers. After lunch, teachers then used their consolidated notes to customize their own plans for classroom implementation. A template was provided to each teacher, who word-processed their plans in the afternoon. By 4:00 PM, all implementations were recorded on Dr. Stuessy's and Dr. Hemingway's computers, teachers had completed their final evaluation forms, and teachers were dismissed to leave for home either on Wednesday evening or Thursday morning.

Evaluator's Comments

Communication among Presenters:

On a daily basis, presenters, project leaders and graduate students read and discussed the daily concerns sheets. The discussions consistently were centered on how to enhance content and presentations. Discussions were a free flow of information from different perspectives and as a result, the sessions became even better during an already outstanding workshop. The degree of professionalism displayed by all was a pleasure to observe. The presenters were well prepared and could easily adapt to changing conditions, teacher-participant technical background or individual classroom dynamics.

Roles of Graduate Students:

The graduate students involved in this workshop worked with the teacher-participants and became a part of each group. They not only improved their own skills but made observations and posted comments from their perspective. Their ability to be both a student (teacher-participant) and an observer was a complex task but they meet or exceeded those goals.

Addressing of Participants' Needs:

All those tasked to deliver this workshop made good use of the daily concerns sheets. The teacher-participants had ample time to reflect and write their concerns, which ranged from content details and implementation to personal matters. Ways to address teacher-participants' concerns were discussed. These concerns were addressed the following morning, either to the teacher-participant class or individually if necessary. When talking to the teacher-participants, they were satisfied and pleased with the quick turn around on addressing their concerns.

Flexibility in Scheduling:

The schedule was stable and yet maintained a flexibility to better accommodate all those involved in the project. Scheduling was discussed at the daily meeting of the project staff. On task and on time were primary, with minor changes to better meet the learning needs of the teacher-participants. The schedule consistency and structure was appreciated by the teacher-participants and their preparation for classes as well as the project personnel. It was particularly helpful from an observation and evaluation vantage point.

Use of Daily Feedback Sheets:

Daily formative evaluation (feedback sheets) is one of the best methods to evaluate the progress and effectiveness of any project, if reviewed on a daily basis. This project used this information effectively to fine-tune an excellent workshop. Project personnel and teacher-participants were served well by this simple daily reporting. It only requires a small amount of time of the teacher-participants to think and reflect on the day's activities. By sorting through the day's activities, teacher-participants put the day's learning in perspective and it give the project personnel a snapshot of how well the information presented was received and digested.

General Comments:

It is unusual to observe the degree of professionalism seen in this project. All of the project personnel and teacher-participants were on task and fully engaged for the entire time. The few problems that arose were solved quickly and efficiently. Technical content, collaboration, use of electronic data sources and teaching skills were seamlessly wrapped into the workshop. The project goals were met or exceeded and all involved appeared to benefit and enjoy the experience.

This project and the presentation team could readily serve as a benchmark or model for professional development in the sciences.

DRK12 2009 Annual Report Supplemental Supporting Documents

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I. Major Achievements and Progress to Date

A. Annual Progress Report for PlantingScience Partners

2009 PROGRESS REPORT

May 2009

by Claire Hemingway, Education Director, Botanical Society of America

I. Project Activities Overview

Key Activities from 2007-2008 Progress Report Submitted April 17, 2008:

- **PlantingScience Online Learning Community participation doubled during 2007-2008. (48 schools, 1,233 students working in 368 teams and 120 scientists signed on as mentors, including 17 members of the Master Plant Science Team)**
- **Alpha field-testing of respiration, corn competition, and genetics modules.**
- **Hiring of a project coordination initiated.**
- **Planning for first Summer Institute for Teachers to be held August 4-13, with scientists Dr. Marshall Sundberg (Photosynthesis and Respiration) and Dr. Beverly Brown (Seed germination) and Teacher Leaders Toni Lafferty and Allison Landry.**

Overview of 2008-2009 Progress:

- **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 2009 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.**
- **Continued relationship building, now 10 societies and organizations partner in PlantingScience.**

II. Curriculum Writing, Field-Testing, and Disseminating Activities

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

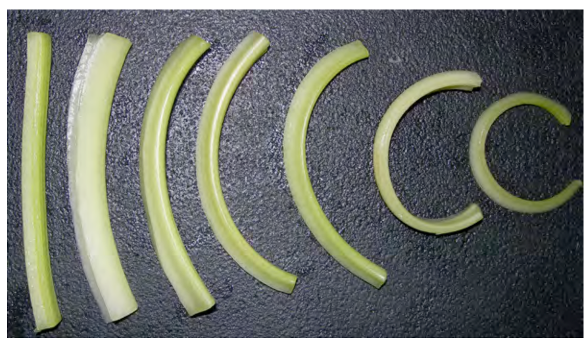
Renee Lopez-Smith of Southern Illinois University will lead the science content development in collaboration with local Illinois teachers, whom she will identify through the SIU GK-12-supported project led by Dr. Karen Renzaglia. Renee is a GK-12 fellow in this program and connections to the secondary 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 ONLINE LEARNING COMMUNITY 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

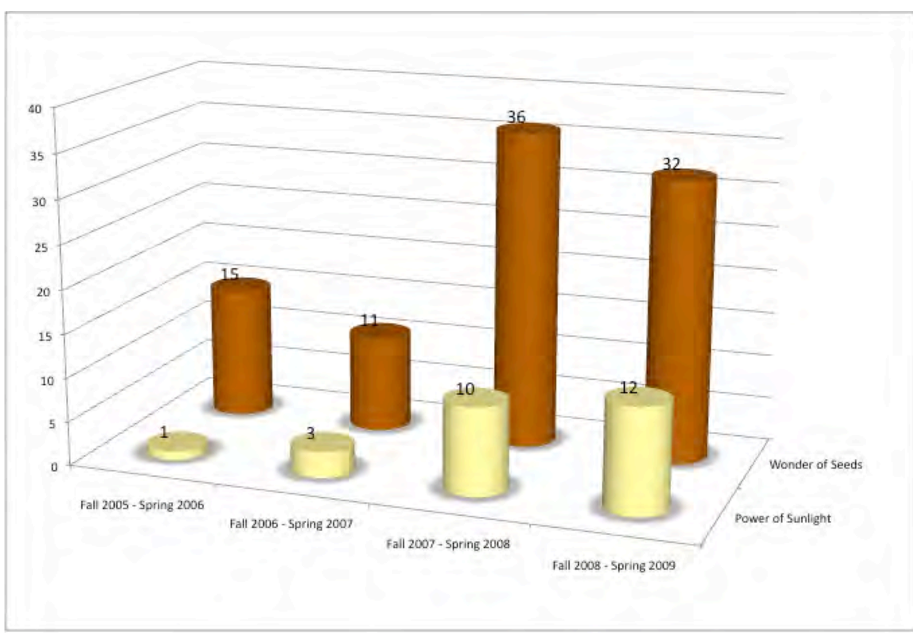
Discussion Forums, with other individuals actively participating by starting threads and replying. Although most members of the online community participate as silent onlookers, the number of views clearly indicates. Barriers to participation in the Discussion Forum have not been systematically addressed 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.

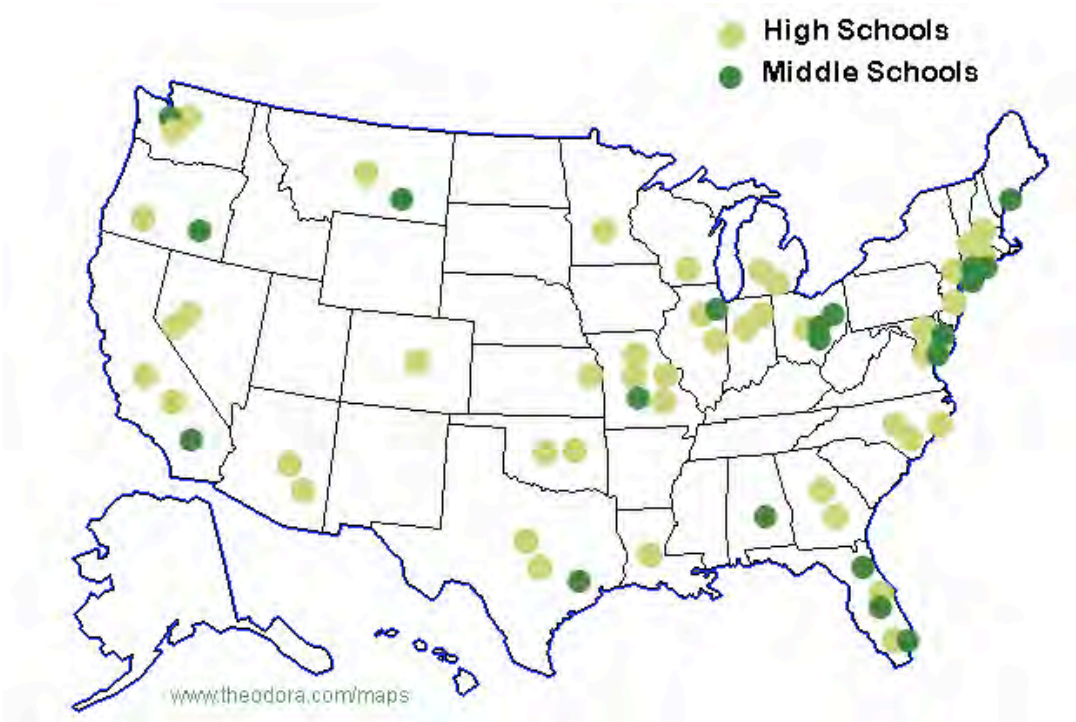
Participation by teachers: This academic year saw three changes in teacher participation during the online mentored inquiry sessions: greater involvement of multiple classes from the same school; increases in field-testing teachers; and inclusion of teachers who had prior summer professional development 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

	High School		Middle School	
Participation by Academic Year (Fall and Spring Online Sessions)	**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

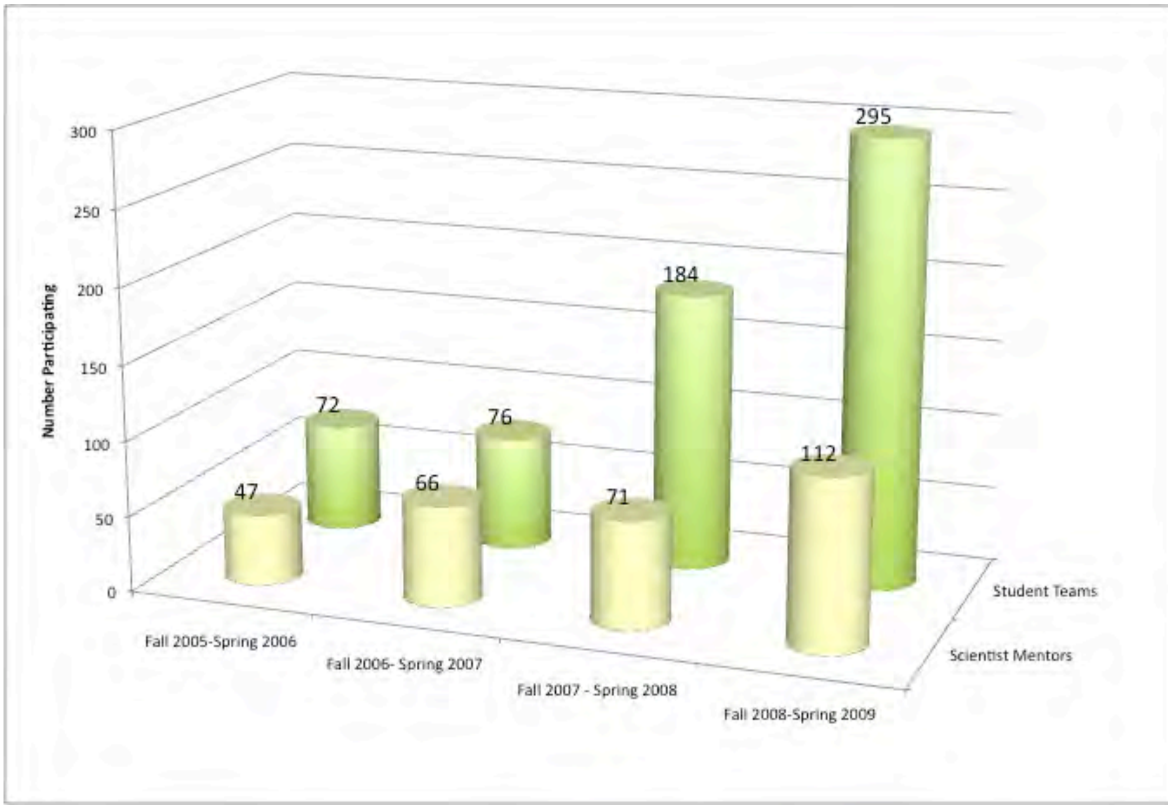
High school and middle school student postings to team research web pages show some remarkably similar patterns. Teams of both student groups typically post research questions, predictions, and plans for a research design to answer the question posed. Students appear to get bogged down primarily in the 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 – Spring 2009 (434 teams)	85.7% (n=372)	79.2% (n=344)	75.6% (n=328)	53.7% (n=233)	49.8% (n=216)	29.3% (n=127)	17.3% (n=75)	34.3% (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.

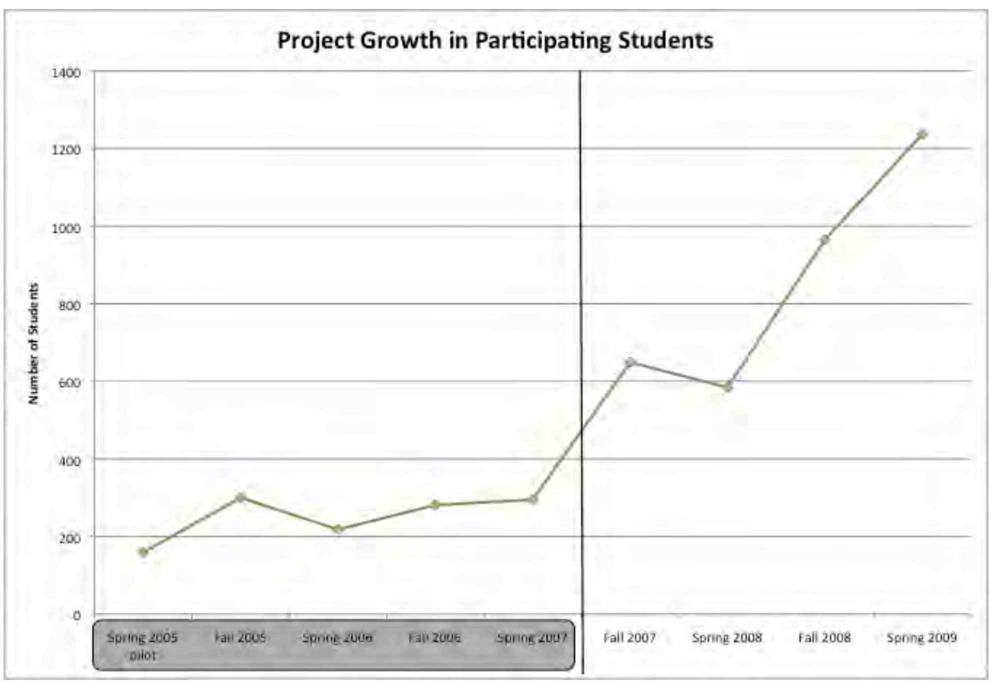
Analysis of pre- and post-tests is ongoing; therefore, selected anecdotal comments about what students liked most and least about the experience are provided below.

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.

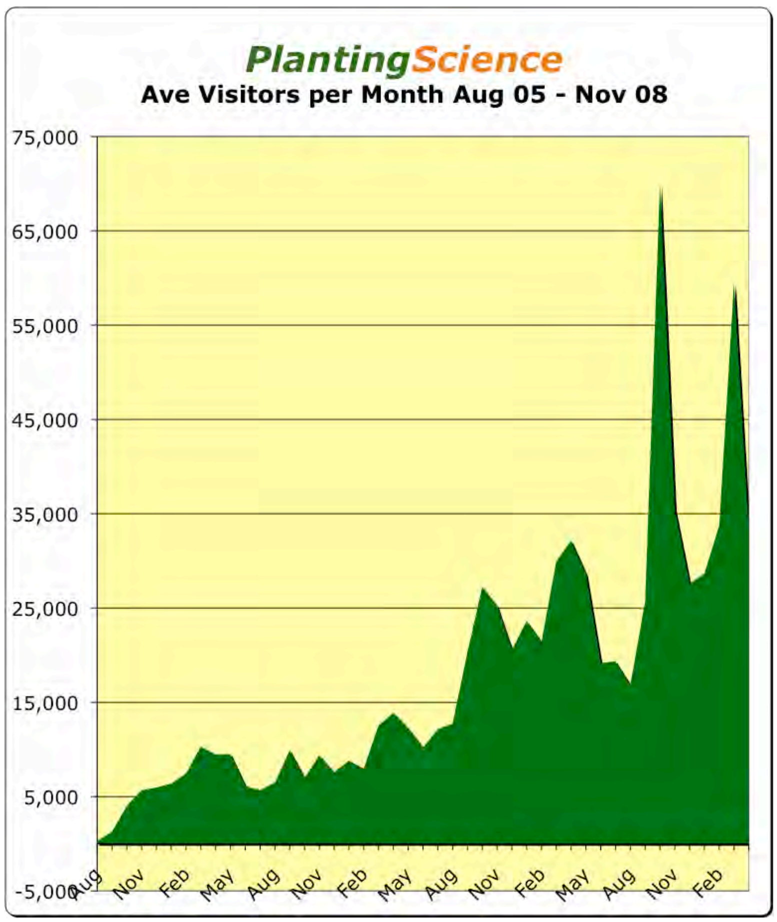


Increases in scientist participation rose 59% from last year's level, which allowed the program to accommodate the student increases. Larger numbers of scientists were possible not only due to greater involvement by members of the Botanical Society of America, but also volunteers from additional societies 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 December-January are presumably influenced by teachers exploring the internet.



II. Project Schedule

II. Project Schedule. A. Implementation, evaluation, and dissemination timeline (Proposal Table 2), annotated.

	Summer Activities	School Year Activities
Year 0	Modules A & B: Develop and Field test Scientist Mentorship Recruitment	Modules A & B: Review Study (C. Packard, Sisters Middle School)
Year 1	Develop and integrate new web tools and resources **[Ahead & Behind]** 2-Week Institute (16 teachers)-Modules A (Wonder of Seeds) & B (Power of Sunlight) **[On Schedule]** HS teacher-Scientist Co-author Modules C & D **[On Schedule & Behind]** Scientist Mentorship Workshop and Recruitment **[On Schedule]** Presentations/workshops at NABT, NSTA, etc. **[On Schedule]**	Modules A & B: Implement and Evaluate **[On Schedule on most aspects]** Modules C & D: Field test and Review **[Behind on aspects]** Classroom Observations **[On Schedule]** Workshop Evaluation / Questionnaires **[On Schedule]**
Comments Yr 1 Schedule	**New web tools and resources** ahead of schedule include developing database queries for tracking online community and improving student registration. Integration of online pre-and post-tests occurred during school year, but improvements needed. **Curriculum development** was on schedule for C Module development the Brassica strand of the Genetics module, behind schedule for the Arabidopsis strand. Field-testing of Respiration and Corn competition was on schedule. Module writing and web integration behind schedule. **2 Classrooms Observed** during school year (case studies included in this Annual Report). Evaluation of modules and online work is partial.	
Year 2	2-Week Institute (16 teachers)-Pilot Modules C Genetics: Arabidopsis and Brassica Strands) & D (Pollination) **[On Schedule]** HS teacher-Scientist Co-author Modules E & F **[Behind on aspects]** Scientist Mentorship Workshop and Recruitment [Ahead of schedule] Presentations/workshops at NABT, NSTA, etc **[On Schedule]**	Modules A-D: Implement and Evaluate Modules E & F: Field test and Review Classroom Observations Workshop Evaluation / Questionnaires
Comments Yr 2 Ahead and Behind Schedule	**Scientist recruitment** is substantially **ahead** of schedule, with 10 society partners committed, which is already translating to increases in mentors. **Web tools and resources behind** schedule include improving website look and functionality and integrating new curricular features. **Curriculum development behind**, **but plans underway to redress this**, and content for modules to pilot at 2010 summer institute identified and pre-alpha testing by scientists ongoing.	**Project is currently going into the Summer season of Yr 2. Yr 2 School year activities to be covered in subsequent report.**
Year 3	2-Week Institute (16 teachers)-Pilot Modules E & F HS teacher-Scientist Co-author Modules G & H Scientist Mentorship Workshop and Recruitment Presentations/workshops at NABT, NSTA, etc.	Modules A-F: Implement and Evaluate Modules G & H: Field test and Review Classroom Observations Workshop Evaluation / Questionnaires Draft Booklet
Year 4	2-Week Institute (30 teachers, using all modules as content for professional development workshop) Pilot classroom connections in middle school Scientist Mentorship Workshop and Recruitment Presentations/workshops at NABT, NSTA, etc.	Modules A-F: Implement and Evaluate Classroom Observations Workshop Evaluation / Questionnaires Distribute Booklet at NSTA, NABT
Year 5	Scientist Mentorship Workshop and Recruitment Authentic Science Conference at Professional Meetings	Modules A-F: Implement Case Study Analysis / Full Scale Use and Final Products

III. Opportunities for Training and Development
A. Professional Development Activities for Teachers
1. Teacher engagement in PlantingScience activities, with numbers impacted

Engagement: type, number, and intensity of involvement	Individuals Involved	Description of Involvement and Impact
Online PlantingScience Learning Community Teachers N = 53 classes from 48 schools, 2,202 students fall session = 24 teachers spring session = 29 teachers	**High Schools:** 455 students in fall session; 752 students in spring session. **Middle Schools:** 287 students in fall session; 667 students in spring session	Teachers and their students register online. Student teams are connected to online mentor on their team research web page. Teachers have access to mentors through private message system and online discussion forum.
1st Summer Institute Teachers August 4-13, 2008 Texas A&M University • Teacher Participants N =13; 15 accepted, 2 later declined • Teacher Leaders N = 2 Post-workshop Engagement • Teacher Implementers N = 13 9 teachers, 86 students in fall 8 teachers, 61 students in spring • Portfolio Teachers N = 4 • Classroom Researchers N =3	**Participants (Teacher Leaders underlined):** Ninah Butler; Rachelle Carnes; Francisca Enih; Michael Hotz; Rebecca (Johns) Brewer; Toni Lafferty; Allison Landry; Jill Lisius; Barbara Simon-Waters; Tamica Stubbs; Lisa Thompson; Kathleen Vanderloop; Naomi Volain **Implementers:** all of above **Portfolio (received by 29 May):** K. Vanderloop; R. Brewer; F. Enih **Classroom case studies:** M Hotz; T. Lafferty, L. Thompson	Participants engaged in 5 days of immersion with seed germination, plant growth, photosynthesis and respiration, followed by 5 days of building inquiry teaching and learning skills. Teacher leaders shared their previous classroom expertise using PlantingScience modules piloted at workshop. Implementers took part in either fall &/or spring online mentored inquiry session. Portfolio teachers reflected on teaching and learning. Case study teachers have GA researcher video tape class.
2nd Summer Institute Teachers to be held June 8-16, 2009 Texas A&M University • Teacher Participants N=17 accepted, 4 declined to date. 4 returning from 2008 • Teacher Leaders in Workshop N = 3	**Participants (Teacher Leaders underlined):** Jenn Carlson; Joann Chartrand; Angela Harrison; Michael Hotz; Betty Indriolo; Toni Lafferty; Allison Landry; Jennifer Reis; Lori Rosburg; Kiran Satyavarapu; Dina Tucker; Angela Turner; Kathleen Vanderloop; Bill Welch	As with last year, teachers will engage in intensive science immersion experience, working collaboratively in small teams of fellow teachers and closely with scientists, followed by individualized skill building sessions determined by teacher needs and interests.
Teachers engaged in writing and field-testing curricular modules N = 2 teachers, 75 students in fall N = 4 teachers, 93 students spring	Toni Lafferty; Allison Landry; Valdine McLean; Kathleen Vanderloop	Teachers engaged in writing and field testing work closely with scientists and project team. Materials are provided to their classroom to support activities.
Teachers engaged in workshops N = 3	Carol Packard co-hosted session at NSTA Portland Regional. Toni Lafferty and Allison Landry contributed to session at NSTA National Meeting in New Orleans.	Teachers share with fellow teachers at national science education meetings their experiences with PlantingScience.

2. Summer Workshop Schedules

a. Daily Schedule-At-a-Glance for June 2009 Teacher Institute. This was provided to teachers on 5/4/2008, along with logistics information, login details for the PlantingScience website, and a pollen collection protocol to collect pollen samples from their local environment with slides mailed to them prior to the Texas workshop.

b. Detailed Daily Schedule of Activities, Resources and Logistics Needs. Co-created and shared among Summer Institute presenters and contributors: Hemingway, Williams, Griffing, Brown, Stuessy, Honda, Woods, Robertson, and Texas A&M University Graduate Students.

plantingscience.org

2009 Summer Institute Schedule Snapshot

Time	Mon 6/8	Tue 6/9	Wed 6/10	Thu 6/11	Fri 6/12	Sat 6/13	Sun 6/14	Mon 6/15	Tue 6/16
8:00-8:30		Insights, questions	Insights, questions	Insights, questions	Insights, questions	Insights, questions	**On Your Own** **R&R** **Explore Holistic Garden, Rec. Center, Etc.**	Insights, questions	Insights, questions
8:30-10:00	Welcome, HouseKeeping, How (Planting)Science Works. Thinking Like a Scientist	What are Characteristics of the Environment?	Genetics Break out Groups. F1, Did Mendel invent Punnett	Pollinators Thinking Like A Bee. Selection and Mating	Pollinator Movement Experiments	Taking Science Immersion and PlantingScience Experience to the Classroom		FLEX Options: Classroom Researcher, Engaging with multimedia, Observations	Lingering Questions, Preparing for Online Session
10:00-10:15	**Break**	**Break**	**Break**	**Break**	**Break**	**Break**		**Break**	**Break**
10:15-11:45	Thinking Like A Plant	Genetics Break out Groups. Where to begin investigations?	Genetics Break out Groups. Observations and Data	Phasing Inquiry, Roundtable Team Share Questions	Genetics Break out Groups. Team Work Time	Establishing Environment Sequencing, Maintaining Momentum		FLEX Options: Photosynthesis, Science Notebooks, TBA	Share Implementation Plans
11:45-1:00	**Lunch Break**	**Lunch Break**	**Lunch Break**	**Lunch Break**	**Lunch Break**	**Lunch Break**		**Lunch Break**	**Lunch Break**
1:00-2:30	Set out Pollen Slides, Testing Phenotypes	Collect Slides Pollen, Incompatibility, Plant Strategies	Pollen Digital Image Library	Genetics Break out Groups, Visit Growth Facilities	Making Connections	Science Talk and Storyboards in the Classroom	Teacher Plant Inquiry Material Share	FLEX Options: Germination, Examining Student Work, TBA	Final Questions, Last Thoughts, Next Steps
2:30-2:45	**Break**	**Break**	**Break**	**Break**	**Break**			**Break**	**Feedback Head Home**
2:45-4:15	Getting to Know the Organisms	Genetics Break out Groups. Variation, Mendelian and Multigenic Inheritance	Exploring Tools for Analysis	Genetics Break out Groups.	Roundtable Team Share Data	Science Talk with Online Mentors	Tailoring Inquiries for Your Class	FLEX Options: Sense making, Concept maps, TBA	
4:15-4:45	Insights, questions	Insights, questions	Insights, questions	Insights, questions	Insights, questions	Insights, questions	Insights, questions	Insights, questions	
4:45-5:00	Daily Feedback	Daily Feedback Form Teams for Website	Daily Feedback Teams post to web	Daily Feedback Teams post to web	Daily Feedback Teams post to web	Daily Feedback Teams post to web	Daily Feedback Teams post to web	Daily Feedback Teams post to web	
PM	Options	Readings	Video Options	Lab Options	Party Option	Options	Video Options	Interviews	

PlantingScience 2009 Summer Institute Schedule

5/28/09 Synthesis of Collaborative Input

	Monday 8 Jun	Tuesday 9 Jun	Wednesday 10 Jun	Thursday 11 Jun	Friday 12 Jun
0.5 hr		Claire initiate with input from all: insights, questions, connections Carol: housekeeping /logistics	Claire initiate: Discussion of insights, questions, connections Carol: housekeeping /logistics	Claire initiate: Discussion of insights, questions, connections Carol: housekeeping /logistics	Claire initiate: insights, questions, connections Carol: housekeeping /logistics
8:30-10:00 (1.5 hrs)	Welcome, Expectations and Options: Case Study Teachers, Returning Teachers, Portfolios [Claire and Carol] Houskeeping Carol Teacher intro-ice breaker PS Experience Overview Thinking Like A Scientist www.understandingscience.org Science Works Chart [Claire] Handout Lab Notebooks to all.	Paul, Larry, and Bev: What is environment? Characteristics of an environment. Genetics break out groups: RCB: Paul, Amber, and Teacher Leader Kathy At: Larry & TL Toni & Allison how to make light box, operational thoughts	Genetics break outs, with teacher leader input: Paul, Amber: F1 population observations, data gathering, questions to be asked with this populations, emphasis on environment Larry: Mendel did not invent the Punnett square	Bev: Pollination Phase 3A Word splash warm up (10 min) Concept Map (10 min) Think like a bee (15 min) Plant's point of view (15 min) Introduce experimental tools and design form (15 min) 9:30-10:00 Paul: Selection and mating in F1, questions to investigate in F2	Bev: Pollination Phase 3B Teams conduct pollinator movement experiments 3 15-min obs. periods [transport teachers to & from hort garden]
10:00-10:15	Break	Break	Break	Break	Break
10:15-11:45 (1.5 hrs)	Bev: Individuals draw life cycle in notebook, note environmntl influences (5 min). Lab pairs explore Arabidopsis and Brassica at various stages, randomly arranged, and arrange in life stage (8 min). Pairs document life cycle thinking: posters, drawings, photos (15 min) Min. paper: What do you know now about plant life cycles that you didn't know before?(2 min) Rotate to form new lab pairs. Larry & Paul: Pairs compare phenotype of 2 Arabidopsis and 2 Brassica. Draw, list, photo, plant parts and pollen. Is this phenotype the consequence of genotype or the environment? How would you test it? Compare pollen phenotypes. Are these haploid phenotypes? [45 min] Adds/changes to poster [15 min]	10:15-11:00 Genetics break outs: Paul, Amber: Seed or the Pod? Where does the investigation begin? What can you teach with a seed pod? Larry: The Inbred life: Variability in Arabidopsis. What is a RIL?	Genetics break outs to 11 am. F1 population observations, data gathering, questions to be asked, cont.	10:15-11:15. Claire, Sandy, Teresa initiate, with input Paul, Larry, Bev, teacher leaders: Inquiry phased from guided to open and formulating a question (all strands together) 11:15-11:45. Roundtable discussions of team questions.	Genetics break outs, with teacher leader input: Amber: Data analysis across generations. What were the grand parents like? What genotypes might the children carry? Analysis of the role of the environment in variation. Connections of the phenotypic data and genetics to evolution. Teams work on data to share with group. Continue working with tools.
12:00-1:00	Lunch Break	Long Lunch Break - teachers can pick up slides	Lunch Break	Lunch Break [Paul leaves]	Lunch Break
1:00-2:30	1-2:00 Larry: Demonstration of potential tests for phenotype a consequence of environment/genotype. 2:00-2:30 Paul and Larry: Brassica	1:30-2:00 Bev: Pollen is? Warm up (10 min); introduce /demo tools, e.g., pollen.com, others explored later (10 min); brainstorm hypothesis (10 min) 2:00-2:30 Paul and Larry:	(Meet in Larry's microscopy lab?) 1:30-2:30 Bev: Pollination Phase 2 Stain slides and document to create pollen image library (60 min) Could start Learning the Tools before 2:45 if slide staining, examination, and	1:00-200 Genetics break outs, with teacher leader input: Amber: F2 population observations, data gathering possible extra experiments with F2 seeds relating to environment and expression	Thinking Together in Rm 301 1:00-1:30 Genetics teams create concept map/or storyboard 1:30-1:45 Joining the

PlantingScience 2009 Summer Institute Schedule

5/28/09 Synthesis of Collaborative Input

	Basics (Getting acquainted with Brassica family) Overview together [30 min]	Pollination and self incompatibility Beeing the bee in Brassica Cross pollination and emasculation in Arabidopsis	capturing images takes 60 min. Could include video conference with Valdine	Larry: trichome , pigment data Team time working with tools 2 pm-3:00 Walking field trip to Greenhouse/Growth chamber. Teacher tasks 1/2 drawing/taking photo of phenotypic variation. ½ tasked with noting environmental variation	genetics stories 1:45-2:15 Pollination teams create poster of pollination movement data. 2:15-2:30 Individuals draw life cycle in notebook
2:30-2:45	Break	Break	Break-walk back to Harrington		Break
2:45-4:15	2:45-3:30 Paul: Brassica Life Cycle Spiral (Growth, development, reproduction, variation) 3:30-4:00 Larry: Arabidopsis Comparisons and contrasts 4:00-4:15 Bev: Intro to setting pollen slides, discussion of the slides that they received and set out prior to arriving in Texas	Genetics break outs, with teacher leader input: Paul: Launching the investigation (scientific method, experimental design, review of language of genetics)- Variation, generation, genetic aspects, methodology, connections between topics Larry: Multigenic inheritance	Learning the Tools. All. (Rm 303 or Larry's microscopy lab) Image J, Cameras, Computers, Excel. Teams working on their own data. Bev: Examine slides. Image J/Excel Paul: F1 data analysis, tools for analysis on paper and in Excel, questions to investigate in the F2 Larry: trichome and pigment data	3:00-3:15 Break-walk back to Harrington 3:15-4:00. Genetics break outs, with teacher leader input: F2data analysis, tools for analysis on paper and in Excel 4:00-4:15. Teams run final ideas by Bev for approval	2:45-3:05 Round table discussions of teacher team genetics projects. 3:10-3:40 Round table of pollination projects 3:45-4:45 Pair-share and discussion: taking it to the classroom, adjusting to learner levels, student assessment
4:15-4:45	Introduce discussion insights, questions, connections & "Parking Space" post it notes	Claire initiate: Insights, questions, connections, class application	Claire initiate: Insights, questions, connections, class application	Claire initiate: Insights, questions, connections, class application	Continue discussion
4:45-5 pm	Teacher feedback forms	Form teams for website Teacher daily forms	Teams post to website Teacher daily forms	Teams post to website Teacher daily forms	Teams post to website Teacher daily forms
5:00	Daily debrief Paul, Amber, Larry, Bev, teacher leaders, Teresa, Sandy, Claire, Carol, GA.	Daily debrief	Daily debrief	Daily debrief	Daily debrief
PM	Teachers choose locations in garden in front of hort. greenhouse and vicinity to set out pollen traps	Reading and homework: GMO ways of controlling seed distribution	Optional: Science talk – video recording External evaluator interview PW, BB	Optional: Lab open for team work and building digital library for class External evaluator interview LG,AR	Group party
Resources Needed / Logistic Considerations	• Entire day in Rm 303 • For each teacher pair (n=8 pairs) Arabidopsis and Brassica sets of life cycle plants consisting of seed, germination, seed, vegetative growth phase, plants in bloom, plants with fruit, plants in senescence. • Poster sized paper, colored markers, glue, tape • Color printer • 1 digital camera/tripod per team (so, need total of 10)	• Break out Rms 303 and 301. • 1 Video Camera for each rm. • Transportation or time for slide pick up • Blackboard or whiteboard • Chalk or markers • Materials for each team to construct light box: crates, lights, foil, etc. (4 Brassica sets and 4 Arabidopsis sets—Toni will bring her 5 At sets) • Imaging microscopes • Flowering Arabidopsis	• Break out Rms 303 and 301. • 1 Video Camera for each rm. • Larry's microscopy lab • Blackboard or whiteboard (maintain data table to be modified by teachers) • Chalk or markers • Image J • 10 Cameras • Computers • Memory sticks for images/data • Excel • Microscopes • Arabidopsis RILs in petri dishes/sucrose	• Break out Rms 303 and 301. • 1 Video Camera for each rm. • Blackboard or whiteboard • Chalk or markers • Poster sized paper, colored markers, glue, tape • 4 sets of plants in bloom. 6-8 plants per set. Set 1: Plants of same species, same height, different colors Set 2. Plants of 2 spp, with different flowers, same height Set 3. Plants of 2 spp. Same	• Transportation to garden • Break out Rms 303 and 301. • 1 Video Camera for each rm. • 6 ft bamboo poles—10 per team (80 total) • floral water piks –20 per team • floral tape • poster paper • computers • color printer • markers • glue or tape • Memory sticks for

	• Magnifiers, hand lenses • Razor blades, dissecting needles • Dissecting scopes • Poster-board size Post-Its • Video camera for Rm 301	separated by transparency sleeves • Dissecting materials, hand lenses, etc. • Seeds for each RIL • Petri dishes, microwaved utensils for planting • Sterilized bleach and rinse • Sucrose solution • 10 Cameras • PlantingScience website	started end of May • Arabidopsis RILs started mid-May with leaves incubated for 48 hrs in sucrose solution • Fuchsin basic stain for pollen slides	flower color, different height Set 4. Diverse with some flowering more abundantly • Database of SEM of Arabidopsis seed from RILs • Information from Larkin/Marks on trichomes in RILs • Image J • 10 Cameras • Computers • Memory sticks for images/data • Excel	images/data • Excel

Notes:

Room Logistics, Wireless access in Harrington Hall:
Room 303. Large classroom with IT (projector/screen/computer) console, sinks for wet labs, movable tables, attached science stock room. Room 301. Adjacent medium sized room with rolling IT cart and screen, movable tables (but no wet lab facilities).

Teacher teams:
~ 8 teams of 2 teachers. Different pairs in pollination inquiry and genetics inquiry. Teams record thinking in individual lab notebooks, on posters/paper/white board, and on website.

Dynamics of Presenters and Teacher Leaders.
During the break out groups Paul, Amber, and Larry will seek input from Kathy, Toni, and Allison about classroom logistics, learning goals for students at different levels, concepts or logistics their student find challenging. Fellow teachers will need and want to hear the experiences of their fellow professionals.

During large group discussions of insights, questions, and connections, Claire will also encourage their voices to be heard, along with input from Teresa based on her insights facilitating the curriculum development. Claire will initiate the large discussion, but let Paul, Amber, Larry, &/or Bev lead depending on where teachers conversations flow.

Video taping of each day.
Digital video cameras placed unobtrusively in corner of rooms will record sessions. Videos will be used to inform curriculum development and internal evaluation.

PlantingScience 2009 Summer Institute Schedule

5/28/09 Synthesis of Collaborative Input

	Saturday 13 Jun	Sunday 14 Jun	Monday 15 Jun	Tuesday 16 Jun
8:30-10:00	Transition from science immersion to the PlantingScience classroom and online experience / The Website Revisited [Claire]	Time off R&R on your own	Option 1: Classroom researcher options [Carol] Option 2. Building digital library for classroom [teams &/or individuals] Option 3. Observations [Teresa]	8:30-8:45 Lingering questions 8:45-9:20 Preparing for an online session [Claire or Jen] 9:20-10:00 Implementation small group [Carol]
10:00-10:15	Break		Break	Break
10:15-11:45	Establishing Environment; Sequencing Activities; Allowing Time for Immersion; Maintaining Momentum [Carol]		Option 1: Photosynthesis & Respiration [Sandy] Option 2. Weaving concepts, skills, inquiry [Teresa] Option 3. Science notebooks [Claire]	10:15-10:30 Jigsaw group to share implementation strategies 10:30-11:20 Complete implementation plans 11:20-11:45 Inquiry assessment and Post-CLES survey
noon	Lunch		Lunch	Lunch delivered
1:00-2:30	1:00-1:30 Insights from PlantingScience teachers 1:30-2:30 Science Talk in the Classroom [Sandy]	Teacher plant inquiry material share and swap.	Option 1: Germination [Sandy] Option 2. Assessment [Amber?,Teresa] Option 3. Selected by group	Final Questions, Last Thoughts, Next Steps
2:30-2:45	Break	Break	Break	Teacher final feedback forms
2:45-4:15	2:45-3:3:45 Science Talk with Online Scientist Mentors [Claire, Amber?] 3:45-4:15 Portfolio option [Carol]	Tailoring inquiries for classroom –staging guided to open, using video talking point [Claire, Teresa, Sandy]	Option 1: Story boards and sense making [Sandy] Option 2. Concept mapping as a learning tool [Carol] Option 3. Selected by group	Final Debrief after teachers leave
4:15-4:45	Discussion of insights, questions, connections	Discussion of insights, questions, connections	Discussion of insights, questions, connections	
4:45-5:00	Teacher daily feedback forms	Teacher daily feedback forms	Teacher daily feedback forms	
5:00	Daily debrief	Daily debrief	Daily debrief	
	External evaluator interview CS and GA	External evaluator interview teachers	Post-technology and Barriers Interviews External evaluator interview CH, SH, TW	
PM		Option: video conversations	Option: time lapse germination videos	

3. Reflection on teacher school year implementation (fall 2008, spring 2009)

Self-reflection: Portfolios from 3 Teachers who attended the 2008 PlantingScience Summer Institute and Implemented during School Year.

Kathy Vanderloop – **4 year's teaching** experience.

Appleton West High School (Appleton, WI). **Suburban** school.

Student population: **77% Caucasian**, 12.5% Asian, 5.5% Latino/Hispanic, 4% African American, 1% Native American.

<u>Applied Genetics Elective Class</u>

Field-testing the Rapid Cycling Brassica strand of the Genetics Module. Field test involved Kathy working closely with Dr. Paul William, developer of the Wisconsin Fast Plants, C. Hemingway, and plant genetics graduate student Brunilis Burgos, with weekly conference calls prior to and during the field test. Kathy learned about the genetics module in development during the 2008 Summer Institute. She preferred to participate in genetics field testing with her Genetics Elective Class rather than either of the modules she mastered during the Summer Institute, because she already used Wisconsin Fast Plants with her genetics students in mono-hybrid crosses and wanted to expand her ability to use Wisconsin Fast Plants with her genetics students.

Rebecca Johns Brewer – **9 year's teaching** experience.

Troy High School (Troy, MI). **Suburban** school.

Student population: **70% Caucasian**, 24% Asian, 2% Latino/Hispanic, 3% African American, 1% Native American.

<u>Freshman General Biology Class</u>

Implementation of Wonder of Seeds Unit. Following extensive experience with both the Power of Sunlight and Wonder of Seeds modules at the 2008 Summer Institute, Rebecca chose to implement the Wonder of Seeds with her General Biology class.

Planting Science Portfolio – Kathy Vanderloop

Teacher Profile

Kathy Vanderloop
Appleton West High School
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(920)766-7919 (home)
(920) 419-0103 (cell)
vanderloopkath@aasd.k12.wi.us

As a fifth year teacher, I currently teach sophomore Biology and Applied Genetics. Sophomore biology is a required course for graduation and Applied Genetics is a semester long elective course. I have also taught 7th grade Life Science, Meteorology, Earth Science and freshmen Physical Science. For next year, I will be writing curriculum and teaching one or more of the following new courses: Food Science, Oceanography or Geology.

I try to incorporate a variety of teaching strategies in my daily lessons so that I can reach as many students as possible with a learning method that they are comfortable with. Some strategies include: wet and dry labs, inquiry labs, direct instruction and note taking, student collaboration and presentation, position papers, research papers, discussions, white-boarding for review of concepts and sometimes worksheets to involve repetition of vocabulary and concepts. I like to utilize different teaching methods so that the students are more involved in their own learning.

I chose to implement PlantingScience in my classroom because I thought that interaction with science mentors would be a great new experience for high school students. This would be another tool to get students interested in plants and science. My students are woefully ignorant about how plants grow, reproduce and ultimately produce the food that they eat. They truly have limited knowledge of plants in general, specifically how to grow them, plant parts and function and even basic gardening terminology. For example, during the fast plants inquiry, many of my students were unaware that plants sexually reproduce and did not know what it meant to pollinate a plant.

School and Class Profile – demographics of school and class population

The city of Appleton has a population of 72,000 people, but the school district boundaries include the surrounding area. The total population that the school district covers is closer to 90,000 residents. Appleton West is one of three high schools and is located in the downtown area. Its student population is roughly 1600 students. West is the most diverse school in the district and has a disproportionately large share of students from a low socioeconomic background. The average teacher to student ratio overall is 27.5 to one. Of the 26 Applied Genetics students who participated in the pilot experiment, 21 were white, one black and three were Hispanic . There were 14 boys and 12 girls in the class.

Appleton West Enrollment by Ethnicity

	1991 1992	1996 1997	2001 2002	2006 2007	2008 2009
American Indian	10	7	9	9	21
Asian/Pacific Islander	42	48	126	159	171
Black	7	19	28	62	68
Hispanic	23	25	35	69	10

Percent of Student Population Characterized as Non-White

	1991 1992	1996 1997	2001 2002	2006 2007	2008 2009
	5.6	6.6	13.7	20.4	23

Percent of Student Population Categorized as Low Income

	1991 1992	1996 1997	2001 2002	2006 2007	2008 2009
	6.1	9.9	17.0	27.0	29.0

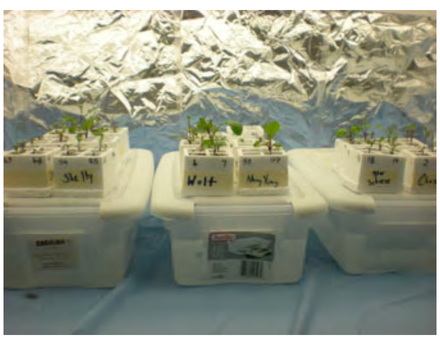
Student Work

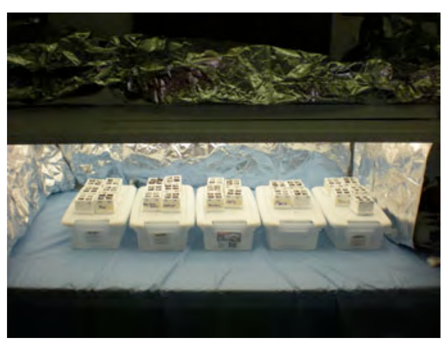
Attached as a separate pdf file are several samples of good student work and several samples of poor work. I chose the attached assessment because it served as a wrap-up of the inquiry. Danielle was a struggling student in this class. She did not have a strong background in genetics and was more comfortable learning materials in a rote fashion. As this course was entirely geared around applying knowledge to new situations, she struggled throughout the entire semester. An example of good work included those assessments by Kassy and Meng. Both were students who genuinely were curious and wanted to make sure they were following correct lab protocol and were more than willing to spend extra time asking questions for clarification. They were also the ones that took the lead and interacted with their mentors.

As part of the assessment, there was a question asking for student feedback regarding the experience of interacting with science mentors. Overall, the students enjoyed the inquiry and came up with a variety of reasons as to why plants turned out the way they did. The students were , however, somewhat confused throughout the project. For many, this was the first time they had done a true inquiry lab where there was no “right” answer to the lab question. The lack of written instructions was problematic for some. Journaling was also a struggle for several students who had never been required to do this before. They were unsure of what they should be writing. . After we got started, they seemed to settle in and figured out what they needed to do.

Below are pictures of various students planting their seeds and collecting data.


MICHIGAN


Wolf



Teacher Written Reflection on student attitudinal and content knowledge.

Student's attitudes were very positive throughout the entire project, even when they were unsure of what they were doing. Overall, the students enjoyed working with their online mentors and the only grumbling I heard was that there wasn't enough time to do everything. As far as content knowledge, students were able to take away from this experiment a couple of very important conclusions with regard to "doing" science: things don't always come out the way you planned, good science measurement and data collection really does depend on the details, sometimes science is tedious (measuring and counting) and sometimes your ideas are way off. The good parts are when data ends up the way you predicted. (Mendelian traits of purple/tall, green/dwarf)

As an aside, I have recently had conversations with three of the students from this class and have discussed this lab. Even though they did not get the results that we had planned on, and that our data did not match Paul's, they felt that they learned more about the process of science more than they had in any of their previous science classes. They thought it was worthwhile doing the investigation and they enjoyed interacting with the mentor scientists rather than just following directions for a regular lab activity. They also helped me to brainstorm what we could change to make the investigation even more worthwhile for this coming semester.

Classroom Context

Class periods are 50 minutes long.

Time Study – The following is a schedule of time spent on this lab.

10/23/08 – 35 minutes. Introduce fast plants and discuss upcoming pilot project. Discuss how seeds are planted, equipment used and how we would care for the plants in the coming weeks.

10/29/08 – 50 minutes. Plant seeds, water, label and place under grow lights.

11/4/08 – 50 minutes. Measure height, cotyledon width, start journal entries.

11/7/08 – 40 minutes. Data posted online and first interaction with mentors.

11/10/08 – 50 minutes. Measure plant height, team pictures uploaded, leaf hair count. Choose 25 "most hair" plants and 25 "least hair" plants for pollination.

11/12/08 – 50 minutes. First pollination, height to first flower, number of leaves on stem.

11/14/08 – 30 minutes. Using the same bee stick, complete second pollination.

11/17/08 – 11/24/08 – About five minutes per day to water and move plants on grow boxes.

12/3/08 – I snipped plants, taped and identified by number until seeds could ripen (about **30 minutes)**

12/8/08 – 50 minutes. Count seeds, number of pods, plant F2 generation.

12/11/08 – 40 minutes. Post data, discussion.

12/16/08 – 25 minutes. Assign assessment and discuss what expected for write-up.

12/17/08 – 50 minutes. Measure cotyledon width, observations on stem color.

12/19/08 – 20 minutes. Start work on assessment write-up

12/23/08 – 50 minutes. Count leaf hairs, final postings.

How prepared students for he experience

See above for how I prepared the students during the first pilot investigation. I will definitely do a better job introducing this investigation for the coming semester. I will be requiring that students know more background knowledge of plants and how to grow them. Instead of telling them the information, I will instruct them to find information via a webquest. Some of the questions they will be responsible for will include: what are fast plants, what is a model organism, why are fast plants used in genetics studies, what are pigments and why are they so important for photosynthesis, why do some plants have more than one pigment, the electromagnetic spectrum and relative energy levels, the importance of controlling the environment and planting conditions for the investigation, what are plant's requirements to grow and thrive, plant parts and functions, identification of plant parts, male plant sterility, selfing plants vs. non-selfing plants, reasoned genetic predictions, etc.

Constraints and challenges and how you handled them

Weather and classroom temperature fluctuations impacted our investigation. West is heated to between 68°F-72°F Monday afternoon through Friday morning. On the weekends the thermostat is set back to the low 60s. Thanksgiving break also didn't treat some of the plants very well. The cooler temperatures slowed our growth rate.

Because of the growth rate, time became our enemy towards the end of the inquiry. Claire helped us out by stretching the window that we could post data and converse with our scientist mentors.

Planting Science Field-Testing Teacher Feedback Form
Genetics – Fall 2008

Class Title – Applied Genetics, 1 semester course with a prerequisite of Life Science or Biology and Physical Science. Students enter the course with a basic knowledge of Mendelian inheritance. They should be able to predict phenotype and genotype frequencies for both monohybrid and dihybrid crosses. They should also be able to recognize and deduce phenotypes and genotypes for sex-linked traits, codominance, incomplete dominance and multiple alleles.

Student Grade Level – Junior and Senior

Content Knowledge	1 Little to none	3 Some	5 Lots
Students had previous exposure to Mendel's Principle of Segregation.			X
Students had previous exposure to Mendel's Principle of Independent Assortment.			X
Students had previous exposure to complex patterns of inheritance		X	
Students were familiar with differences between qualitative and quantitative (continuously variable) traits	X		
Students were familiar with concept of genetics and environment influencing phenotype. Students really were unaware as to the effect of the environment on phenotype. They thought that it would be minor at best.	X		
Students were familiar with differences between artificial and natural selection.		X	
Skills			
Students were familiar with recording data in spreadsheets		X	
Students were familiar with creating graphs. Some students were very adept at graphing using Excel, a couple had a problem graphing data by hand.		X	
Students were familiar with analyzing data, such as calculating mean, standard deviation and chi square. Students were very capable of calculating mean and chi square, but not standard deviation. Unfortunately, I haven't had the Excel training yet to feel comfortable teaching it to students. I'm capable of figuring it out by myself, but not confident enough to teach others.		X	
Students had previous exposure to working in teams			X
Students had previous exposure to building arguments based on data. My students have struggled with using the data to support their arguments. They are continually trying to make arguments based upon what they think should have happened, not what actually happened according to their data	X		
What do students need to know to do this inquiry? Describe additional key knowledge or skill base students need for successful implementation. These may be gained during your class. One of the major things that students need to cognizant of is how important it is for them to follow lab protocols and procedures as closely as possible. Not planting seeds exactly like other students, forgetting to water the plants, not counting hairs, leaves, pods, seeds accurately, not counting hairs properly, etc. My students automatically assumed that there was a wide margin of error built into the labs (much like the regular labs they do in science). Students must have a basic knowledge of Mendelian genetics and how to predict phenotypes based on knowledge of the parents and observations of the plants themselves.			

1. **About how much time did it take to prepare for this classroom investigation?**

Other than constructing the light apparatus, the setup for this lab was minimal. Having participated in the summer PlantingScience Institute, I knew what to expect with the science mentors and the process that we undertook. However, had I not participated in the weekly discussions with Claire, Paul, Larry and Bruni, I would have had to take much more time preparing for class. It was during these discussions that I came to understand more about the investigation and what questions I should be asking my students. Had I not been prompted by the group, I would have had to sit down and spend a lot more time trying to figure out exactly what it was we were doing and how to direct the students with what they were doing in class.

2. **About how much class time per week did the students directly engage in this investigation?**

In addition to the timeline outlined above, students also spent about five minutes each day checking their plants, watering plants and moving them so that they did not take root in the felt. Some students neglected this task and consequently ended up with dead plants.

3. **How did you use the class time while waiting for plants to reach the next stage of the investigation? What content did you cover? What hands-on activities did students do?**

Prior to starting the Fast Plants lab, we reviewed mitosis, meiosis, Mendelian genetics, monohybrid and dihybrid crosses, complex modes of inheritance, pedigrees, probability and chi square analysis, epistasis, selective breeding, linkage and sex chromosomes.

During the first week of the inquiry, the students were working on sex chromosomes. They participated in a lab where they made slides of Barr bodies from cheek cells. They also completed a lab finding polytene chromosomes from the salivary glands of Drosophila.

November 3-7	karyotyping activity and a test
November 10 – 14	Perform F2 cross of fruit flies for Drosophia lab
November 17 – 21	DNA structure notes & discussion. DNA replication using online animations to visualize. Work on replication problems worksheet. Start discussion of RNA and transcription
November 24-25	Short week due to holiday. Worked on transcription and translation notes and problems
December 1 – 5	DNA video, Virtual PCR and electrophoresis lab in computer lab, test.
December 8 – 12	Finish fruit fly lab
December 15 – 19	Notes, discussion, review, go over previous work for review. Discuss restriction enzymes. Restriction enzyme paper/pencil lab Mutation and cancer notes and discussion
December 22-23	Cancer Movie – *Cell Wars: Understanding the Mysteries of Cancer*

To finish out the semester, we did a PCR lab, bioethics discussion and paper, electrophoresis lab and gene transformation.with a phosphorescent gene.

Had this been my sophomore biology class, we would have been working on photosynthesis, respiration, mitosis/meiosis and basic Mendelian genetics with monohybrid and dihybrid crosses.

4. Did you have sufficient time for the investigation? If not, why? How might this challenge be overcome?

No, we did not have enough time to really analyze the results of this investigation. There were a variety of reasons why this was but the main reason was that we got a late start in the semester and the plants did not grow at the rate we had anticipated. Part of the reason for the growth rate was a lack of a constant warm temperature in the school building. Since our plants were a bit on the slow side, the experiment ran right into the holidays and past the time when the mentors would normally be available to converse with the students.

For this next semester, I would like to start as soon as possible so that we don't feel rushed throughout the investigation.

5. Is the genetics of the unit important for students in the participating class? Why? Does it reinforce content you would ordinarily teach? Does it introduce new concepts?

The genetics of the unit are absolutely important! This was an opportunity for my students to actually see genetics in action. They were all familiar with what the Punnett square probabilities said should happen, and they could manipulate data to figure out whether variations from the predicted were possibly due to chance or not, but with this experiment, they were able to see that yes, a 9:3:3:1 ratio can emerge from a dihybrid cross. It also introduced the concept of continuous variation. The fact that not all plants grew at the same rate, didn't get to be the same height, nor have the same number of flowers, seeds, etc., gave them something to think about as to how that affects an organism's chances of passing their genes on to the next generation. The hair count data also was a good opportunity for them to understand that there may be more than one gene having an impact on a particular phenotype, or that something else is going on that controls the expression of different genes.

6. Are the genetics goals of the investigation clear to you? Please describe the primary and secondary student learning goals that you wish for your students to achieve through this unit.

The goals of this investigation are for students to actually witness how genetics (and environment) can impact the phenotypes of an organism. It also allows them to see how natural selection can have an impact on which organisms live long enough to pass their genes to the next generation. For example, during our investigation, one of the students was lamenting the fact that her plant was not flowering at the same time as the other plants in the class. This led to a discussion of reproductive fitness. If a plant is not ready to be fertilized when all the other plants are ready, what are the chances that it will pass its genes on?

It also showed the students that not everything can be predicted in rigid Mendelian fashion. Leaf hair numbers, for example, do not subscribe to the proportions of 3:1 or 9:3:3:1 (at least from our data). Something else, or a combination of other genes are contributing to the hairy leaf phenotype.

7. Please comment on your students' achievement of genetics understanding at the end of this investigation. What concepts/skills did they "nail"? What concepts/skills would benefit from reinforcement?

My students were a little overwhelmed at first and were unsure of what exactly we were trying to accomplish. Their comments were that they felt they were "floating" without real direction. Part of the fault for this is mine due to minimal background preparation. The other reason for this feeling was that these students had not had much experience with inquiry-type labs. They were used to having a lab manual and detailed procedural instructions to follow and set questions to answer. Once the experiment was underway, they settled down and started to enjoy the fact that they didn't; have to come up with the one and only "right" answer.

My students "nailed" the prediction of the ratios of the purple/tall and green/dwarf traits. They were able to differentiate between these phenotypes and do a chi square test to make sure the variation could have been due to chance. The hair count data, however, gave them fits. Part of the problem was the fact that measurements were not as accurate as they could have been and that lead to data sets that didn't show any correlations or trends that they could identify.

8. Were there aspects of the hands-on investigation that particularly helped in developing your students' understanding?

My students were able to improve their observational and analytical skills as a result of this investigation. It became quite apparent towards the end that shoddy observations and data collection can really have an impact on the outcome of the experiment and the ability to make any meaningful connections or conclusions at all when using the data.

The pollination of the plants was an education to many of the students. Students understood the role of bees carrying pollen from plant to plant, but they really did not understand that pollen is really plant sperm and that the stigma was the female receptacle for the pollen.

The wide range of variation in hair number, flower number, pod number and seed number were surprising to my students. At first, they could not really see that there were any differences in the setup of the experiment. After some prompting, they were able to develop some ideas of how the environment really could be varied for each of the plants. For example, some students planted seeds deeper than others, some were watered more regularly, some had small pellets of Osmocote, others had larger pellets of Osmocote, some plants may have been under the lights in an area that received more light energy, etc. Once we started discussing these realities, students had an understanding of just how much small changes can have on the life of an organism.

9. **Were there aspects of the online mentoring that particularly helped in developing your students' understanding?**

   The leading questions asked by mentors sometimes stumped the students, but it forced them to think about what could possibly be happening with their plants. There were several students who did quite a bit of posting and they were the ones discussing the questions that were posed to them by their mentors.

   There were also several students who were afraid to post questions for fear that they would sound dumb, or that the question would be thought silly. Even though the students are tech-savvy, they were a bit intimidated by the fact that they were talking with experts in the field of plant science. They knew that their background knowledge of plants was not very deep and so they were hesitant about interacting online for fear that they wouldn't know what the mentor was talking about.

10. **Given the early draft form of the genetics unit, what are the strengths and weaknesses of this unit?**

   One of the major strengths of this investigation is that students are able to see what they have learned through paper/pencil exercises actually occurring over time. It also involves the students in a hands-on learning experience. Any time you can get a student actively involved in the content, they are going to take more ownership of their learning.

   One area that could be improved would be including a bit more background on fast plants. Also, cutting down on the amount of things measured would streamline the investigation.

11. **What needs to be added or deleted to provide enough practice and sufficient challenge for students?**

   Not as many measurements unless they are related or outlined as to what we will be doing with it. We took a lot of measurements last semester, but really didn't tie them all together in any way. For example, if number of leaves is something that really doesn't vary much between plants, perhaps that is something we could skip. Number of flowers, pods, seeds, etc. speaks to reproductive vigor, but we didn't have time to really discuss or analyze this from an evolutionary standpoint. Perhaps this semester I will have more time to do just that. Measuring cotyledons really didn't mean much to the students as well. Does cotyledon width correlate with any of the other characteristics that we were measuring? For the next semester, these measurements will somehow need to be incorporated into the overall project and assessment somehow so that students can see the connections.

12. **What changes would you suggest to make the written materials helpful to teachers? Are there major elements missing that would help teachers guide student investigations in the classroom?**

   A couple of examples of how to figure out the math required to analyze the investigation would be helpful (Statistics for Dummies type of approach). Perhaps a basic-level example to walk students through how to figure out standard deviation, mean and chi square.

Other elements that could be added to improve the teaching of this unit would be to include a listing of questions for the teacher. This will assist them in leading students through a discussion of what is really happening during the lab. I know that our weekly discussions with Bruni, Claire, Paul and Larry were very helpful for me to frame questioning strands for my students. Without these meetings, I would have struggled much more than I did with this activity.

13. Are there any logistic problems that you think can be deleted?

I would suggest planted one quad per pair of people rather than one per person. It will take up less space and be more manageable from a time standpoint.

14. Could a teacher without special training implement this unit?

With detailed instructions and a list of questioning strands, I think that teachers without special training could undertake this experiment and be very successful.

15. What 3-5 things would you like to see improved or changed for the next field test?

For the next time through, would it be possible to plant the seeds in larger quads? We had a fair amount of plants that did not germinate or died because they dried out. Even with the blue wicks and felt, students had to water their plants with a pipette each day to keep them hydrated.

In order to save a little time, I would like to have one quad per two people rather than have each student take care of their own. This will help during the data collection process because I will have both partners do the measuring and counting. Hopefully with both students doing the data collection, they will come up with the same numbers and better accuracy of measurements will be achieved.

From my time management standpoint, I will be requiring that students do a comprehensive background assignment on fast plants, model organisms, pigments, energy and predicting what they will see in this investigation. I will also allow more time for the actual data collection because both partners will count and measure the same data to make sure that we are accurately collecting data.

I would also like to devote more time for online conversations with our mentors and data posting

Name: Danielle Danner
hour 3

Brassica rapa Genetics Inquiry

19/39

Problem: Stem color (purple vs. green) and plant height (tall/dwarf) is a trait that is inherited by subsequent generations in a Mendelian fashion. Is hair count also inherited in this manner or is there something else going on?

Hypothesis:

1

Procedure:

1. Plant F1 generation of *Brassica rapa* plants (grandparents homozygous green/dwarf and homozygous purple/tall)
2. Measure cotyledon width, height to first flower, number of flowers pollinated, number of seed pods, number of seeds and number of hairs on first true leaf.
3. Pollinate top 25% "hairiest" plants together and bottom 25% least hairy plants together.
4. Harvest F1 seeds and replant.
4. Observe number of plants with green vs. purple stems and tall vs. dwarf stature (did not have time for height analysis)
5. Count number of hairs on margin of first true leaf

Background Data/Observations:

1. Attach your journal to this assignment before you turn in. Be sure to include individual and team data. Be sure that it is legible and well-organized.

2. Attach any background research that you did either on the fast plants website or from elsewhere. Be sure to cite the sources of your information. You should have information regarding what *Brassica rapa* is, what it is descended from as far as the plant family, growing cycle, whether it can self-pollinate or not, etc. 1

2

Data & Analysis

"Low" Hair Count Plant Data	Paul's Data	Our Data
A) Average hair number in parental, F1, population is	18	11.6
B) Average hair number in selected low hair parents is	4	/
C) Selection differential for low hair number is (A-B)	14	/
D) Average hair number in F2 progeny selected for low hair	6	13.5
E) Gain from selection for low hair number is (A-D)	12	/
F) Heritability for low hair number is (E/C)	0.86	/

"High" Hair Count Plant Data	Paul's Data	Our Data
A) Average hair number in parental, F1, population is	18	/
B) Average hair number in selected high hair parents is	45	/
C) Selection differential for high hair number is (B-A)	27	/
D) Average hair number in F2 progeny selected for high hair	28	/
E) Gain from selection for high hair number is (A-D)	10	/
F) Heritability for high hair number is (E/C)	0.37	/

1. If the heritability for a trait were h=1, what would that tell you about the inheritance pattern of that trait? (Hint: would it be Mendelian, a complex mode of inheritance, environmental, etc.) Mendelian

2. Does the heritability number you calculated for the class data indicate that hairiness is inherited as a Mendelian trait? How does our class data compare with the "low" and "high" hairs of Paul's data?

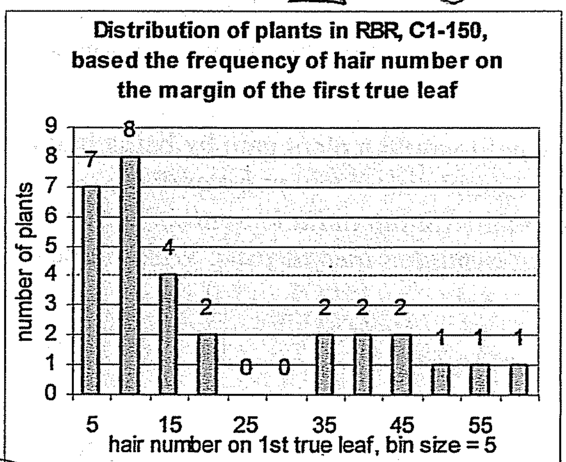
3. Looking at Paul's data (h= .86 for "low" and h = .37 for "high") The difference in heritability is substantial. What do you think this might indicate about the inheritance of variation in leaf hair number?

It might indicate that something else is going on.

4. Prepare a histogram/bar graph of the distribution of plants in RBR, C1-104 based on hair number on the margin of the first true leaf. Use our F1data Compare our results to Paul's. Are they similar? If not, what reasons can you think of for the differences?

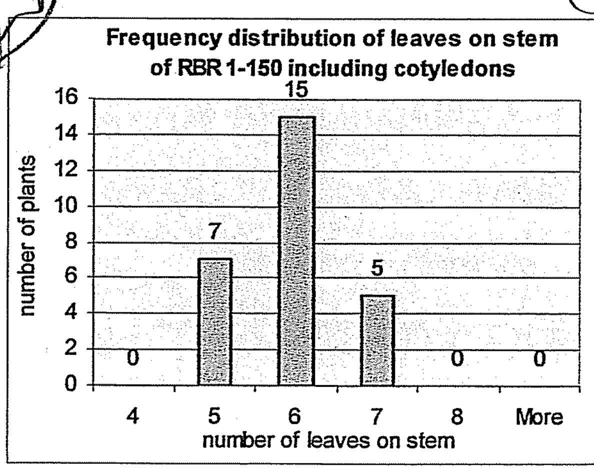
they are similar for the most part. except for more of our plants didn't germinate unlike Paul's plants. we don't have that many differences, in our plant traits.

Paul's Histogram



4. Do the same exercise for number of leaves on the stem of each plant (include the 2 cotyledons on each plant). Why do you think the range of leaves varied so much? Since our seed was all from the same lot of parental plants, why would some plants grow faster than others, be more robust than others, produce more flowers and seeds than others?

① the range of leaves varied so much because some people could have planted their leaves wrong.
② some plants would grow faster because some people may not have watered it as much as other people did.



③ Also some people may produce flowers & more seeds by where they put their plant under the light.

2

③ Didn't get enough nutrients because other plants were shadowing it.

5. Some of our plants did not germinate, but if they did, they died soon after. Give at least three different reasons why you think this occurred.

① One reason why I think this happened is because some seeds were different colors I didn't look as healthy.

② Another reason is because people may not have watered them as much.

6. Based on the data, is hair count heritable as a Mendelian trait? Cite data from this lab to support your position. Do you believe that this conclusion is correct? Why or why not. yes it is heritable as a mendelian trait

3

7. From an evolutionary standpoint, what benefit would a plant gain by being hairy vs. non-hairy? Other hairy plants such as Lamb's ear (*Stachys byzantina*), geranium (*Pelargonium zonale*) African violet (*Saintpaulia ionantha*), the weed that smells like dirty cat litter, Velvet Leaf (*Abutilon theophrasti*). What purpose does hairiness serve? the hairer the leaf the less palatable it is to eat. It could be a survival mechanism.

8. Similar to the last question, what benefit or drawback would having purple/tall trait vs. green/dwarf trait afford a plant with respect to survival?

A taller plant usually tends to live longer than a dwarf or shorter plant. so it would benefit the plant to be a taller plant so they would survive longer — why would they survive longer

Little green plants don't need as many nutrients. And the more camouflage the better. — what evidence do you have to make this inference?

Taller plants may not get eaten by as many plants because of it's height.

3

oe^2 / +

9. Assuming that stem color is a Mendelian trait, and that the F1 generation showed all purple stemmed plants, use the at data gathered for the F2 generation to prepare a chi-square analysis to see if our deviation from expected could be due to chance? Include the chi-square number, degrees of freedom and probability that it is due to chance. Be sure to indicate whether you accept or reject the null hypothesis.

2

degrees of freedom - 1

.18 - probability due to chance

I accept the null hypothesis.

10. If you were to set this experiment up and do it again, what would you do differently?

I would make sure that everybody watered their plant everyday & the exact same amounts. I would also have everybody set their seeds the same amount apart in their pots, so they would grow good.

11. Write your view of your own work on this project and the changes that occurred throughout the process. What are your thoughts on being mentored by scientists. What would have made this a better learning experience. Also, give some feedback on your participation in this project as compared to your team members' contributions and work ethic.

I thought it was strange that some of my plants didn't germinate but others did. I thought we weren't as involved with the scientists as we should have been. If we could have not done other assignments in between the process it would have helped. I thought me & my team mates all put in a good amount of effort during this project, and that it all worked out really good as a team.

8

29,30,31,32
"plantanatvo"

Danielle Danner
1-9-09
hour 3

Fast plant Journal

Day 2 Journal entry #1

·plants are barely starting to bud.
(29,30,31,32)

Journal entry #2

·plants are growing more now
29 & 30 - ½ inch. > hairy > green stem
31 - 1 inch tall
32 - not budded yet - purple stem

Journal entry #3

·plants are taller now
29 & 30 - ½ inch. > hairy > green stem
31 - 1½ inch.
32 - ½ cm. - purple stem

Journal entry #4

over weekend plants grew rapidly:
29: 2½ inches, 30: 2 inches - hairy / green stem
31: 5½ inches, 32: 1 inch - purple stem

Journal entry #5

plants have grown alot more.
29: 3.6 inches, 30: 3.2 inches - hairy / green stem
31: 7.5 inches, 32: 2 inches - purple stem.

Journal entry #6

Plants grew a little more over days.
29: 4.2 inch, 30: 3.5 inches - hairy / gree stem
31: 8 inch, 32: 3.5 inches - purple stem. ⇨

Journal entry #7

~~Plants~~ "least" plants are cut now

29: stays, 30: stays, 31: cut off 32: stays.

Journal entry #8

Plants are starting to dien & not look as green now.

29: cotlyden width: 2 cm.

30: cotlyden width: 1.5 cm

31: cotlyden width: 1 cm.

32: cotlydem width: .5 cm

Journal entry #9

Plant leaves are starting to fall off. No height has been gained.

Journal entry #10

empty out plants into the garabage.

Journal entry #11

talked to scientist / mentor and told them what we did with our plants & how they previously were doing.

Journal entry #12

Planted new plants, only 2 of mine budded (30 & 31)

Journal entry #13

30 & 31: green stem / 30: 1 inch. 31: 1.5 inch

Journa lentry #14

30: 3.5 inch, 31: 2.5 inch } not growing well

Joural entry #15

emptied out plants into garabage

Name: Abdul Guled

30/39

Brassica rapa Genetics Inquiry

Problem: Stem color (purple vs. green) and plant height (tall/dwarf) is a trait that is inherited by subsequent generations in a Mendelian fashion. Is hair count also inherited in this manner or is there something else going on?

Hypothesis: NO I believe its an evioranmental factor.

Procedure:

1. Plant F1 generation of *Brassica rapa* plants (grandparents homozygous green/dwarf and homozygous purple/tall)
2. Measure cotyledon width, height to first flower, number of flowers pollinated, number of seed pods, number of seeds and number of hairs on first true leaf.
3. Pollinate top 25% "hairiest" plants together and bottom 25% least hairy plants together.
4. Harvest F1 seeds and replant.
4. Observe number of plants with green vs. purple stems and tall vs. dwarf stature (did not have time for height analysis)
5. Count number of hairs on margin of first true leaf

Background Data/Observations:

1. Attach your journal to this assignment before you turn in. Be sure to include individual and team data. Be sure that it is legible and well-organized.

2. Attach any background research that you did either on the fast plants website or from elsewhere. Be sure to cite the sources of your information. You should have information regarding what *Brassica rapa* is, what it is descended from as far as the plant family, growing cycle, whether it can self-pollinate or not, etc. -1

Data & Analysis

"Low" Hair Count Plant Data	Paul's Data	Our Data
A) Average hair number in parental, F1, population is	18	11.3
B) Average hair number in selected low hair parents is	4	4.48
C) Selection differential for low hair number is (A-B)	14	6.82
D) Average hair number in F2 progeny selected for low hair	6	13.51
E) Gain from selection for low hair number is (A-D)	12	2.21
F) Heritability for low hair number is (E/C)	0.86	0.32

"High" Hair Count Plant Data	Paul's Data	Our Data
A) Average hair number in parental, F1, population is	18	11.3
B) Average hair number in selected high hair parents is	45	19.48
C) Selection differential for high hair number is (B-A)	27	8.18
D) Average hair number in F2 progeny selected for high hair	28	11.03
E) Gain from selection for high hair number is (A-D)	10	0.27
F) Heritability for high hair number is (E/C)	0.37	0.03

1. If the heritability for a trait were h=1, what would that tell you about the inheritance pattern of that trait? (Hint: would it be Mendelian, a complex mode of inheritance, environmental, etc.) for the low hair could it could be because its close to 1. But for the high its not because its not even close to 1.

2. Does the heritability number you calculated for the class data indicate that hairiness is inherited as a Mendelian trait? How does our class data compare with the "low" and "high" hairs of Paul's data?

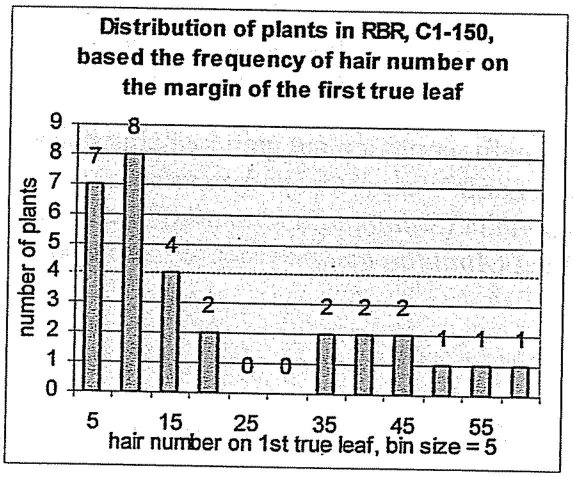
   Our class data suggests that it is not inherited by the mendelian fashion too far away from 1, our class data is also a long ways away from his numbers.

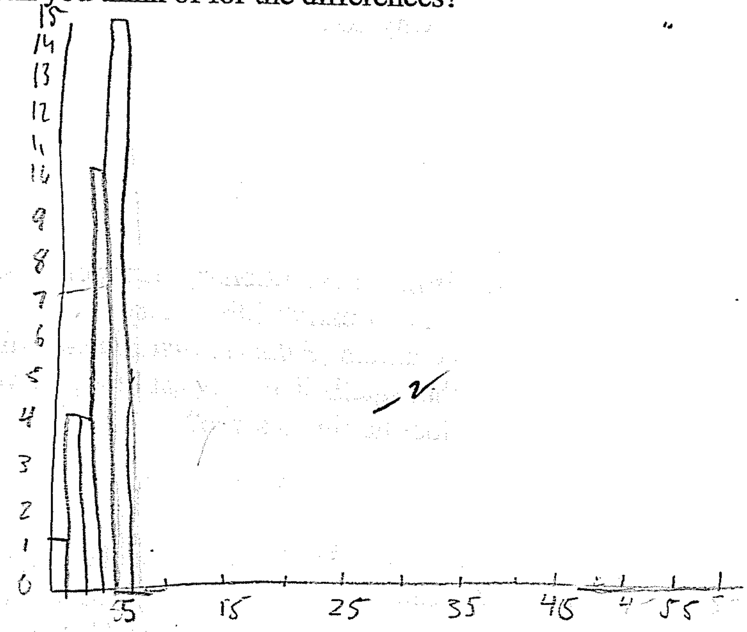
3. Looking at Paul's data (h= .86 for "low" and h = .37 for "high") The difference in heritability is substantial. What do you think this might indicate about the inheritance of variation in leaf hair number?

That it probly is not a mendaline inheratence. Could be an environmental factor.

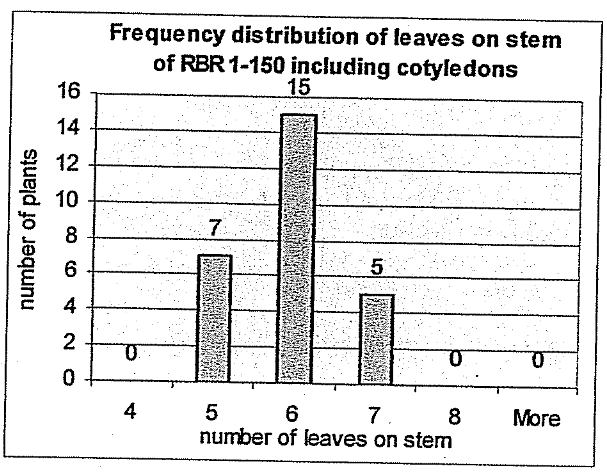
4. Prepare a histogram/bar graph of the distribution of plants in RBR, C1-104 based on hair number on the margin of the first true leaf. Use our F1data Compare our results to Paul's. Are they similar? If not, what reasons can you think of for the differences?

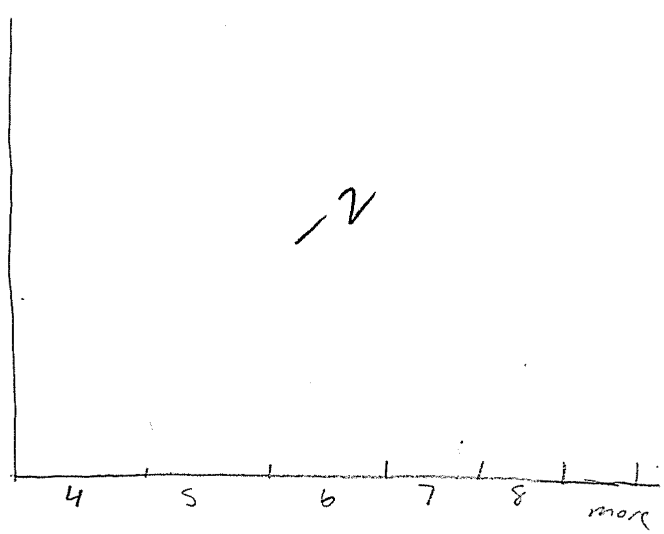
Paul's Histogram





4. Do the same exercise for number of leaves on the stem of each plant (include the 2 cotyledons on each plant). Why do you think the range of leaves varied so much? Since our seed was all from the same lot of parental plants, why would some plants grow faster than others, be more robust than others, produce more flowers and seeds than others?





4

5. Some of our plants did not germinate, but if they did, they died soon after. Give at least three different reasons why you think this occurred.

seed packed down, not as much water some cells were dry.

this is only 1

-1

6. Based on the data, is hair count heritable as a Mendelian trait? Cite data from this lab to support your position. Do you believe that this conclusion is correct? Why or why not.

no because most of the F2 least plants had more hairs than the most plant in the F1 most hair 69 in the least side. in F2 generation

7. From an evolutionary standpoint, why benefit would a plant gain by being hairy vs. non-hairy? Other hairy plants such as Lamb's ear (*Stachys byzantina*), geranium (*Pelargonium zonale*) African violet (*Saintpaulia ionantha*), the weed that smells like dirty cat litter, Velvet Leaf (*Abutilon theophrasti*). What purpose does hairiness serve?

Grip water so it doesnt fall off leaf, or inorder to make it harder for insects to eat plant.

8. Similar to the last question, what benefit or drawback would having purple/tall trait vs. green/dwarf trait afford a plant with respect to survival?

Purple stem will attract more animals since there are not as many. Green is normal. By attracting animals might be steped on or crushed.

actually it's the opposite

9. Assuming that stem color is a Mendelian trait, and that the F1 generation showed all purple stemmed plants, use the at data gathered for the F2 generation to prepare a chi-square analysis to see if our deviation from expected could be due to chance? Include the chi-square number, degrees of freedom and probability that it is due to chance. Be sure to indicate whether you accept or reject the null hypothesis.

-3

10. If you were to set this experiment up and do it again, what would you do differently?

Keep the exprement more controlled. Make sure not to pack soil after putting seed in, Keep the Enviornement different for each cell to see if # of hairs is influenced.

11. Write your view of your own work on this project and the changes that occurred throughout the process. What are your thoughts on being mentored by scientists. What would have made this a better learning experience. Also, give some feedback on your participation in this project as compared to your team members' contributions and work ethic.

I thought it was cool how the mentors got us thinking of possible ways the plants dng instead of just you did it wrong. I also thought it was tough and interesting how they got us thinking about possibilities of why things happened but never actually told us why let us figure it out our selves, I think our group worked well we all did our part and no one slacked off.

3

Abdul Guled
Mrs. Vanderloop
Genetics
3rd hour

10/26/08

One of my seeds did not germinate yet number 87 but the other three cells have started to grow. So far so good.

10/27/08

Just watered my cells put a little extra water on the one that hasn't grown yet hopefully that helps. But my other three are growing fast there already kind of tall except one it's a little on the dwarf side.

10/29/08

The one that hasn't germinated yet has some little green patches growing in it I think I packed the soil down too hard. But the other three are doing pretty good so I hope at least they make it.

10/30/08

Mine have grown comfortably tall but I hope they get bigger then Bob's because his is gigantic and I want mine to grow really big. At least there not curving around like some of the other ones that need toothpicks. We pollinated the plants I made sure I got some tall ones so at least my F2 generation will be really tall. Hopefully no one else thought of that so I have the tallest.

11/12/08

Dang found out we get to pick out seeds not keep our old ones my group picked some out for me hope it's some tall ones. So far it's not looking that great I have two purple one green and number 84 did not germinate.

Name: Meng Yang

Brassica rapa Genetics Inquiry

39/39
Very nice Meng

Problem: Stem color (purple vs. green) and plant height (tall/dwarf) is a trait that is inherited by subsequent generations in a Mendelian fashion. Is hair count also inherited in this manner or is there something else going on?

Hypothesis: If hair count is inherited as a Mendelian trait then our results for hair count should be similar to ratio of stem color, and our heritability should be close to 1.

Procedure:

1. Plant F1 generation of *Brassica rapa* plants (grandparents homozygous green/dwarf and homozygous purple/tall)
2. Measure cotyledon width, height to first flower, number of flowers pollinated, number of seed pods, number of seeds and number of hairs on first true leaf.
3. Pollinate top 25% "hairiest" plants together and bottom 25% least hairy plants together.
4. Harvest F1 seeds and replant.
4. Observe number of plants with green vs. purple stems and tall vs. dwarf stature (did not have time for height analysis)
5. Count number of hairs on margin of first true leaf

Background Data/Observations:

1. Attach your journal to this assignment before you turn in. Be sure to include individual and team data. Be sure that it is legible and well-organized.
2. Attach any background research that you did either on the fast plants website or from elsewhere. Be sure to cite the sources of your information. You should have information regarding what *Brassica rapa* is, what it is descended from as far as the plant family, growing cycle, whether it can self-pollinate or not, etc.

0

Data & Analysis

"Low" Hair Count Plant Data	Paul's Data	Our Data
A) Average hair number in parental, F1, population is	18	11.3
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F) Heritability for low hair number is (E/C)	0.86	.32

"High" Hair Count Plant Data	Paul's Data	Our Data
A) Average hair number in parental, F1, population is	18	11.3
B) Average hair number in selected high hair parents is	45	19.88
C) Selection differential for high hair number is (B-A)	27	8.58
D) Average hair number in F2 progeny selected for high hair	28	11.03
E) Gain from selection for high hair number is (A-D)	10	.27
F) Heritability for high hair number is (E/C)	0.37	.03

1. If the heritability for a trait were h=1, what would that tell you about the inheritance pattern of that trait? (Hint: would it be Mendelian, a complex mode of inheritance, environmental, etc.)

   Mendelian, because it would show that the inheritance isn't due to chance or variation in environment or other factors

2. Does the heritability number you calculated for the class data indicate that hairiness is inherited as a Mendelian trait? How does our class data compare with the "low" and "high" hairs of Paul's data?

   The heritability numbers do not indicate that hairiness is inherited as a Mendelian trait Our class data is not close to Paul's data at all but the data is similar in a way, our low heritability is higher than our high heritability, just like in Paul's data.

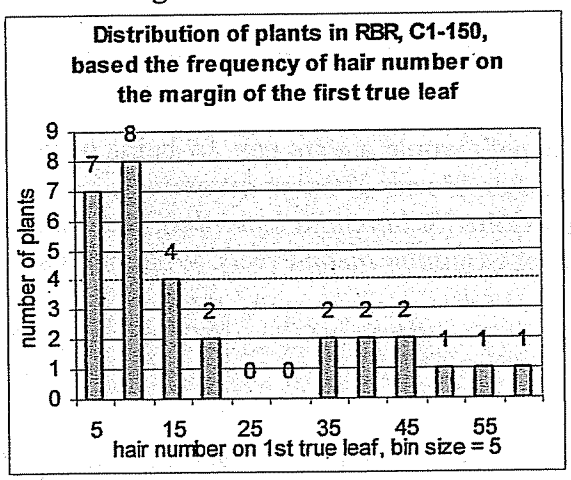
714 '14

3. Looking at Paul's data (h= .86 for "low" and h = .37 for "high") The difference in heritability is substantial. What do you think this might indicate about the inheritance of variation in leaf hair number?

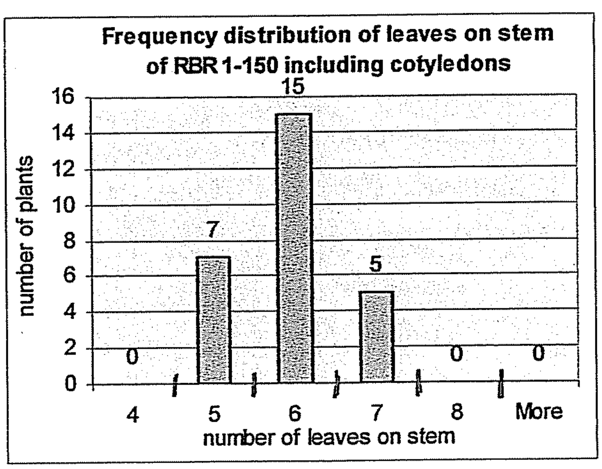
The inheritance is probably not Mendelian and luck could play a factor in the traits of hair count. I think that environment could be a big factor too, because some plants might have more light or water to absorbed.

4. Prepare a histogram/bar graph of the distribution of plants in RBR, C1-104 based on hair number on the margin of the first true leaf. Use our F1data Compare our results to Paul's. Are they similar? If not, what reasons can you think of for the differences?

Paul's Histogram



4. Do the same exercise for number of leaves on the stem of each plant (include the 2 cotyledons on each plant). Why do you think the range of leaves varied so much? Since our seed was all from the same lot of parental plants, why would some plants grow faster than others, be more robust than others, produce more flowers and seeds than others?



6

5. Some of our plants did not germinate, but if they did, they died soon after. Give at least three different reasons why you think this occurred.

- some dried out, not enough water
- not enough sunlight (lamp)
- seed was buried too deep

6. Based on the data, is hair count heritable as a Mendelian trait? Cite data from this lab to support your position. Do you believe that this conclusion is correct? Why or why not.

The data shows that the chances of hair count being Mendelian is low because with an results of .32 heritability for "low" and .03 heritability for "high" hair count plants, it shows that our results were due to some other factors. I don't know if the conclusion is correct because our plants were kind of neglected sometimes so most plants didn't grow as much as it can. I would guess that it was due to the environment that was set-up for the plants, maybe the plants would of been different if we used sunlight instead.

7. From an evolutionary standpoint, ~~why~~ benefit would a plant gain by being hairy vs. non-hairy? Other hairy plants such as Lamb's ear (*Stachys byzantina*), geranium (*Pelargonium zonale*) African violet (*Saintpaulia ionantha*), the weed that smells like dirty cat litter, Velvet Leaf (*Abutilon theophrasti*). What purpose does hairiness serve?

Protection from bugs

I think that being hairy can help plants survival rates because it can be used a barrier from bugs, some plants have spikey hairs, which can hurt whatever is eating it. Hairiness can serve as protection from other plants or it can be used to absorb more sunlight. Being hairy from an evolutionary standpoint could mean better adaptation to the environment, which means higher survival and energy.

nice

8. Similar to the last question, what benefit or drawback would having purple/tall trait vs. green/dwarf trait afford a plant with respect to survival?

maybe caused by anthocyanin due to amount of light or plant is stressed

Some benefit of being tall is that it would be able to absorb more light before it reaches the dwarf plants. Being tall could mean more energy for the plant but it's also more prone to bugs and environmental climates. According to our mentor, she said that purple stem might be caused by Anthocyanin concentration due to the lack of light or stress that the plant undergoes. So I think that purple stem for plants must be stressed from not having enough energy and if it's tall, maybe holding up its own weight is stressful.

nice

FF × FF

9. Assuming that stem color is a Mendelian trait, and that the F1 generation showed all purple stemmed plants, use the ~~at~~ data gathered for the F2 generation to prepare a chi-square analysis to see if our deviation from expected could be due to chance? Include the chi-square number, degrees of freedom and probability that it is due to chance. Be sure to indicate whether you accept or reject the null hypothesis.

Degrees of freedom = 1

	Expected Ratio	observed	Expected	Deviation (o-e)	D²	d²/expected
Purple	3/4	59	63	-4	16	16/63 = .254
Green	1/4	25	21	+4	16	16/21 = .762
		84				x^2 = 1.016
						p = .28

Fail to reject H_0

Null Hypothesis

10. If you were to set this experiment up and do it again, what would you do differently?

I think that I would check up on the plant more frequently because something that happened was that some plants weren't getting enough water or any at all. The area was too little I think, maybe if we do the experiment over again, I would put out more lights to ensure that light was distributed equally. Another factor was that we left the plants at school over the weekends and didn't have a chance to move it around/check up on it, some of my plants died or dried up because of this.

Good pt

11. Write your view of your own work on this project and the changes that occurred throughout the process. What are your thoughts on being mentored by scientists. What would have made this a better learning experience. Also, give some feedback on your participation in this project as compared to your team members' contributions and work ethic.

I think that doing this project I was kind of thrown in as group leader because no one in the group had a clue what we were doing from week to week and most people strayed off task. The majority of the postings online only included two members of the four, I kind of hoped that the other two would do something but at least we got things done. I liked being mentored because she always gave us an explanation for our question regardless of how small it was. Doing this project, it was cool seeing science in action and being a part of it, I love observing the plant and how it changed for generation to generation. I was hoping for the professor to come in and talk to us about the fast plants, this would of helped with understanding the experiment more.

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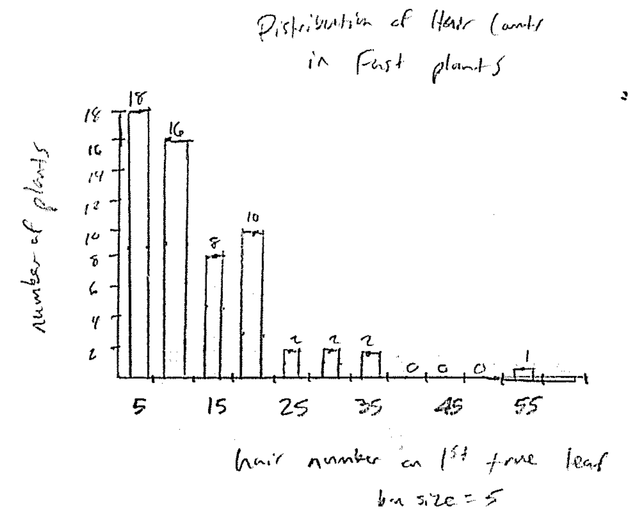
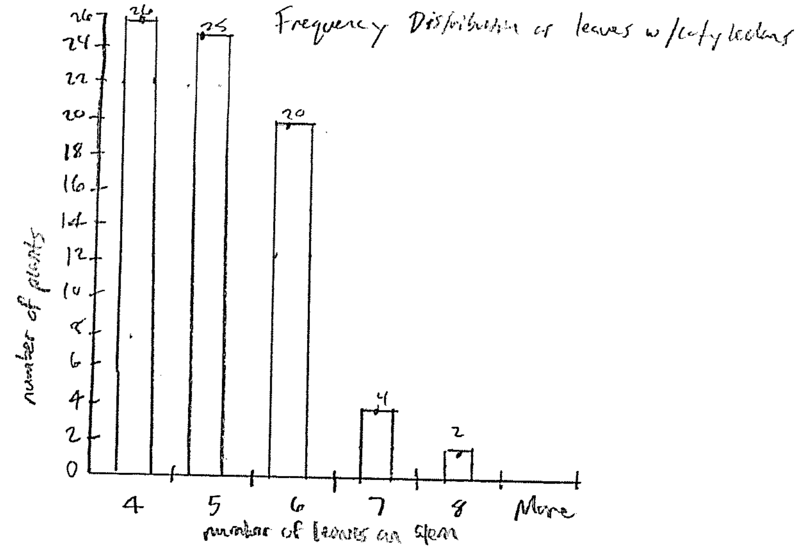


4. Our data is pretty close to Paul's, we both have higher numbers in the low hair count and lower numbers in the higher hair count. Differences can arise based on the environment because in our lab we used lights for the plants and sometimes they were left out for several days before we checked up on them.



4) I think that the number of leaves varied so much because of how fast the plant grew due to better spots that gave it more light. Some plants might of been planted too deep so it wasn't able to grow as much and when we moved the plants, sometimes you pull and the root is stuck. This might stress the plant and affect how much it grows and absorbs light. The leaf variation is also due to its height because the taller most plants were, the more leaves it grew.

www.fastplants.org

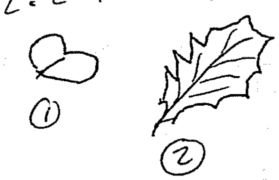
Days = examination/checkup dates

9 tall, purple
3 ~~[illegible]~~ short purple
3 tall green
1 green dwarf

Day 1 11/4

97 + 98 didn't germinate

99 + 100 purple stems jrests stemming out (2:2 leaf shapes)



99 - small leaves, no hair on stem
- two different leaf shapes

100 - tall big leaves
- hair on stem
- two different leaf shapes

99 - 11 mm cotyledon
12 mm - height "

100 - 16 mm cotyledon
height - 30 mm

Day 2 11/6

97+98 - didn't germinate

99+100 - seeds sprouting, growed taller

99 - cotyledon - 11 mm, stayed the same / 3 seeds, hairs developed, little hair
height - 23 mm

100 - cotyledon - 17 mm, growed 1 mm / other leaf (2) got bigger
height - 50 mm, growed a lot taller +20 mm / 13 seeds (moderate amount of hair > p99)

Day 3 11/10

97+98 - didn't germinate

99 - Zero hairs on first true leaf
5 seeds sprouted - yellow
4 leaves
cotyledons are turning purple
3 hairs on stem

Stem height - 62 mm
largest cotyledon - 11 mm

100 - 33 hairs on first true leaf
bottom three leaves are dying - turned purple
23 seeds sprouted - yellow

Stem height - 82 mm
largest cotyledon - dried

* soil dried out over the weekend, some leaves dried

Day 4 11/12

97+98 DNG

99 - leaves turning purple
3 flowers sprouted
4 seeds

height - 76 mm
first flower - 62 mm

Pollination

99 - 104
100 - 74

100 - lower leaves dying - (cotyledons)
middle leaf turning yellow
11 seeds - 6 flowers
leaning

height - 86 mm
first flower - 72 mm

Day 5 11/19

99 - 4 flowers pollinated
2 pods
Total seeds: 12 seeds

) Both plants are same height

100 - seeds on lower branch are dying
6 pods
Total seeds: 16 seeds

Day 1 plant #2

100 - green stem

92-99 - DNG

Day #2 12/17

97 - germinated, purple stem
cotyledon = 9 mm

100 - cotyledon = 10 mm
green stem

Day #3 12/23

97 - purple stem
6 leaves
4 ~~pots~~ flowers

True leafs: 20 (hair)

100 - light green
9 ~~flowers~~
4 leaves

True leafs: 8 (hair)

Print Journals

Name: Kassy Fabbri

39/39. nice job Kassy!

Brassica rapa Genetics Inquiry

Problem: Stem color (purple vs. green) and plant height (tall/dwarf) is a trait that is inherited by subsequent generations in a Mendelian fashion. Is hair count also inherited in this manner or is there something else going on?

Hypothesis: Hair count is not inherited in a Mendelian Fashion. Both tall, short, purple, and green all can have varying numbers of hairs.

Procedure:

1. Plant F1 generation of *Brassica rapa* plants (grandparents homozygous green/dwarf and homozygous purple/tall)
2. Measure cotyledon width, height to first flower, number of flowers pollinated, number of seed pods, number of seeds and number of hairs on first true leaf.
3. Pollinate top 25% "hairiest" plants together and bottom 25% least hairy plants together.
4. Harvest F1 seeds and replant.
4. Observe number of plants with green vs. purple stems and tall vs. dwarf stature (did not have time for height analysis)
5. Count number of hairs on margin of first true leaf

Background Data/Observations:

1. Attach your journal to this assignment before you turn in. Be sure to include individual and team data. Be sure that it is legible and well-organized.

2. Attach any background research that you did either on the fast plants website or from elsewhere. Be sure to cite the sources of your information. You should have information regarding what *Brassica rapa* is, what it is descended from as far as the plant family, growing cycle, whether it can self-pollinate or not, etc.

Paul

0

Data & Analysis

"Low" Hair Count Plant Data	Paul's Data	Our Data
A) Average hair number in parental, F1, population is	18	11.3
B) Average hair number in selected low hair parents is	4	0.56
C) Selection differential for low hair number is (A-B)	14	10.74
D) Average hair number in F2 progeny selected for low hair	6	13.51
E) Gain from selection for low hair number is (A-D)	12	-2.21
F) Heritability for low hair number is (E/C)	0.86	0.212

"High" Hair Count Plant Data	Paul's Data	Our Data
A) Average hair number in parental, F1, population is	18	11.3
B) Average hair number in selected high hair parents is	45	19.88
C) Selection differential for high hair number is (B-A)	27	8.58
D) Average hair number in F2 progeny selected for high hair	28	11.03
E) Gain from selection for high hair number is (A-D)	10	0.27
F) Heritability for high hair number is (E/C)	0.37	0.031

1. If the heritability for a trait were h=1, what would that tell you about the inheritance pattern of that trait? (Hint: would it be Mendelian, a complex mode of inheritance, environmental, etc.) 1.

Mendelian

2. Does the heritability number you calculated for the class data indicate that hairiness is inherited as a Mendelian trait? How does our class data compare with the "low" and "high" hairs of Paul's data?

The low hair number trait appears to be mendelian for Paul's data. However, the high hair number for Paul's data does not appear mendelian. Our data has much lower h values than Paul's and reject Mendelian Inheritance

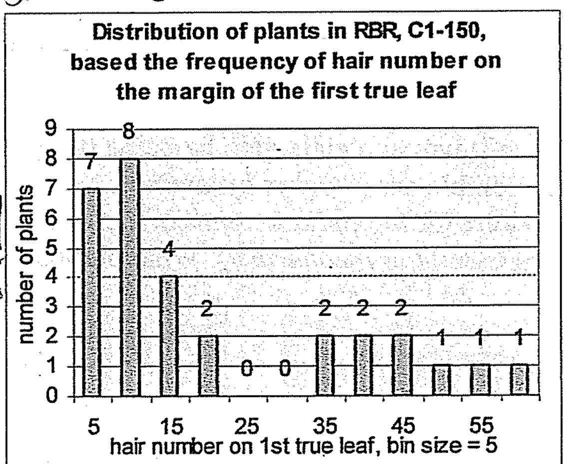
3. Looking at Paul's data (h= .86 for "low" and h = .37 for "high") The difference in heritability is substantial. What do you think this might indicate about the inheritance of variation in leaf hair number?

The low hair appears to be Mendelian inheritance. Perhaps the gene is stronger in expression than high hair. However, the high hair h value is small and appears to be inherited in a non-mendelian trait. There must be other factors or an alternate form of inheritance that is unknown. More research is needed.

4. Prepare a histogram/bar graph of the distribution of plants in RBR, C1-104 based on hair number on the margin of the first true leaf. Use our F1data Compare our results to Paul's. Are they similar? If not, what reasons can you think of for the differences?

0-4	28
5-9	18
10-14	8
15-19	10
20-24	3
25-29	2
30-34	2
35-39	0
40-44	0
45-49	0
50-54	1

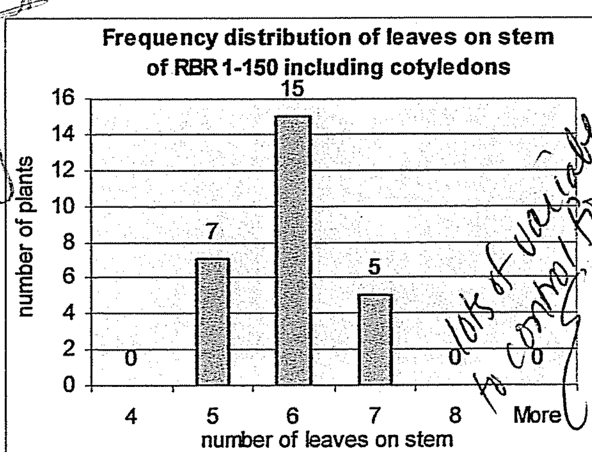
Paul's Histogram



They are a little similar in the fact that lower hair #, 0-10, was the most frequent. We had fewer high numbers than Paul.

We weren't completely similar because of our counting error and variances in plant growth progress, some leaves had no hair because they weren't mature. [OR] multiple genes affecting traits.

4. Do the same exercise for number of leaves on the stem of each plant (include the 2 cotyledons on each plant). Why do you think the range of leaves varied so much? Since our seed was all from the same lot of parental plants, why would some plants grow faster than others, be more robust than others, produce more flowers and seeds than others?



lots of variables to control for

All the plants of F_1 grew at irregular paces from one another. Some were larger/more mature with more leaves. Environmental factors affected the growing of the plants. Depending on the seeds' placement in the soil, their varying darkness, hydration, and other plants' progress, the plants could mature or better succeed to be more robust, taller, faster and have more flowers. Those darker, well-hydrated, and well-[illegible] plants grow taller quicker (more flowers, seeds). These tall plants could hoard nutrients and block access to light + water of smaller/slower plants to be big & have many flowers/seeds

5. Some of our plants did not germinate, but if they did, they died soon after. Give at least three different reasons why you think this occurred.

(1) Buried too deep beneath the dirt & could not receive substantial sunlight

(2) wicks alone were not efficient enough to hydrate the plant (not enough H_2O from pipette either)

(3) Neighboring plants shaded smaller plants or hoarded nutrients with larger roots

6. Based on the data, is hair count heritable as a Mendelian trait? Cite data from this lab to support your position. Do you believe that this conclusion is correct? Why or why not. There is not enough evidence to say hair count is inherited in a Mendelian fashion. Paul's data only partially (for low) supports Mendelian with h=0.86. However high hair data doesn't concur with h=0.37

more research will have to be done and our data is so filled with error it isn't worthy of supporting Mendelian inheritance. I believe Mendelian isn't correct b/c there are outside unknown factors affecting hair #.

7. From an evolutionary standpoint, why benefit would a plant gain by being hairy vs. non-hairy? Other hairy plants such as Lamb's ear (*Stachys byzantina*), geranium (*Pelargonium zonale*) African violet (*Saintpaulia ionantha*), the weed that smells like dirty cat litter, Velvet Leaf (*Abutilon theophrasti*). What purpose does hairiness serve? It fends off predators because it is harder to eat and can better survive

8. Similar to the last question, what benefit or drawback would having purple/tall trait vs. green/dwarf trait afford a plant with respect to survival?

A purple plant is darker than the small plant and can therefore attract more sunlight to itself. The purple plants are also larger and can soar over the green plants to receiving sunlight or dropped H_2O. Green dwarf plants may be shadowed. Since purple/tall plants may need more nutrients to supply a larger plant, they may hoard nutrients or lack nutrients. Green dwarf plants do not need as much nutrients for survival, more chlorophyll for photosynthesis.

interesting observation

$\frac{3}{4}$ 59 p
$\frac{1}{4}$ 25 g

9. Assuming that stem color is a Mendelian trait, and that the F1 generation showed all purple stemmed plants, use the at data gathered for the F2 generation to prepare a chi-square analysis to see if our deviation from expected could be due to chance? Include the chi-square number, degrees of freedom and probability that it is due to chance. Be sure to indicate whether you accept or reject the null hypothesis.

	Ex.	Observed	Ex.	Deviation (O-E)	D^2	D^2/e	
Pur.	$\frac{3}{4}$	59	$\frac{3}{4}(84) = 63$	59-63 = -4	16	16/63	= 0.254
Gr.	$\frac{1}{4}$	25	$\frac{1}{4}(84) = 21$	25-21 = 4	16	16/21	= 0.762

$x^2 = 1.016$
D of F = 1

0.18 accepts Null Hypothesis
↳ prob. that variation is due to chance; our variation may be b/c of chance

10. If you were to set this experiment up and do it again, what would you do differently?
I would take more care with measurements since our results seemed so inaccurate. Especially for plant hair counts, I would double check. I think I would also compare my results more frequently to the class as a whole or view their plants. Most of the time our group observed only our pods. If possible, I might test different environments to compare the effects of temp. or sun-light on the plants.

11. Write your view of your own work on this project and the changes that occurred throughout the process. What are your thoughts on being mentored by scientists. What would have made this a better learning experience. Also, give some feedback on your participation in this project as compared to your team members' contributions and work ethic. This experiment was a learning experience for us all. The next time around, I expect more accurate results. I think if we had more class discussions about observations or mentors' ideas we could come to more conclusions about growing factors. Our mentor was a joy to converse with. I would say it was the highlight of our group checking out answers to our questions. They let us know if we were on the right track, possible correlations, and packed our brains with lots of growing/planting knowledge. As a group, I believe we all were pretty equal in participation. We wrote/thought of questions for our mentors together, helped during absenses, took turns filling out data and we conversed about observations.

Thus, I rate my contributions equal the rest of my group. The experiment itself was quite the task. Overall, this lab makes us think and infer explanations. It's a rather worthy college-prep higher thinking lab.

We planted our identical plants and measured height, leaves, hairs, cotyledon widths, & flowers of the F1. We then pollinated low/low hairs with high/high hairs producing pods with seeds. We replanted the seeds and repeated measurements except with color/height variation.

I noticed the 1st gen. was a motley crew. All the plants, though from same parents, grew in all different manners. It's probably partially to blame for poor results. However, the 2nd gen grew almost synchronized. Perhaps the seeds were whacky or our improved seed planting placement helped.

The lab was time consuming and required work, but it's an important conceptual/procedural lab for preparation for higher level courses. It's worthy of repetition. Hopefully the next group can mend our error.

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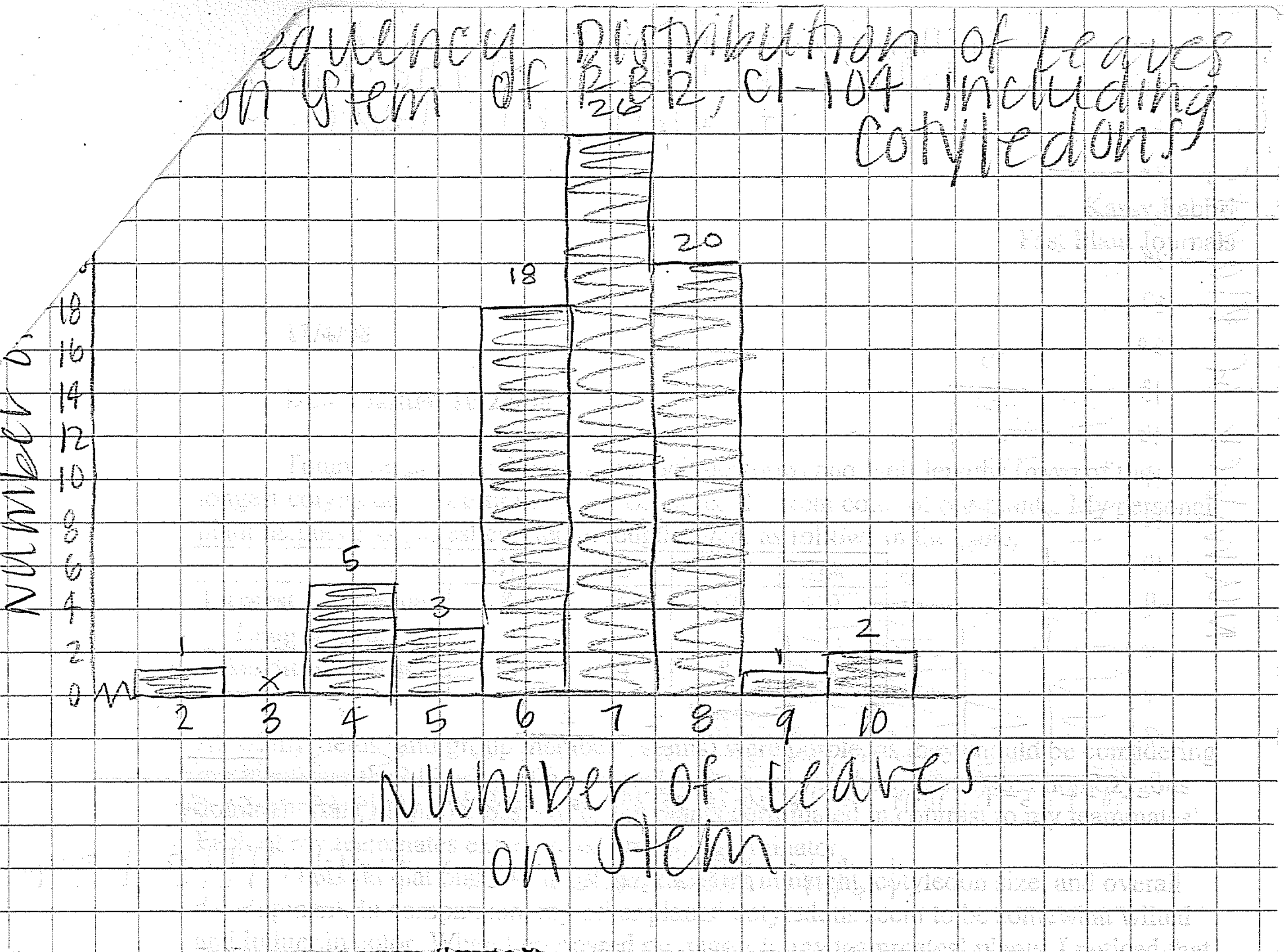

39 seemed to be dark in color and wilted. However, this pod had the tallest plants. Additionally pod 45-48 was unable to be measured for cotyledon width, for no true leaves have sprouted yet. As related to my teammates' plants, mine were the second tallest. As for why I am unsure considering my pod was on the same water tray as the pod that didn't germinate quickly enough. I presume my seed size or fertilizer pellet was larger than the pod that didn't germinate as quickly.

Initially, my pod was placed on the second water tray from the left. Today, I placed the pod on the far right water tray to see if that will have any effect on the progress of my plants. I predict that the increased intensity from the reflection of the heat blanket will allow my plants to prosper. In general, I noticed the middle tray plants were the smallest in height and maturity.

11/6/08

	41	42	43	44
Plant Height (mm)	22	16	31	18

Today we measured plant heights, and all of Kathryn's cotyledons have grown in. All the plant heights have increased by at least 2 mm within 2 days. 43 is now the tallest instead of 41 and 42. In fact, 42 is now the smallest.

Numbers 41 and 44 appeared dry or dehydrated, and the leaves were dark around the edges and veins.

Kassy Fabbri
Fast Plant Journals

11/4/08

Date Planted 10/27/08

Today we measured our plants' heights (mm) and their lengths (mm) of the longest cotyledons. Additionally, we observed the stem color of our plants. My personal plant heights and largest cotyledon lengths were as follows in the table:

	41	**42**	**43**	**44**
Largest Cotyledon Length (mm)	8	7	12	9
Height of Plants	13	14	8	8

All of my stems (and group members' stems) were purple, as they should be considering our plants are the offspring of a homozygous recessive (short, green) and homozygous dominant (tall, purple) cross. All of my plants germinated in contrast to my teammates'. Each of my teammates experienced one non-germinator.

I noticed that plant 43 is the largest plant in height, cotyledon size, and overall development. In comparison, my other plants' cotyledons seem to be somewhat wilted and lighter in color. When I compared my plants to my teammates' plants, I noticed that 39 seemed to be dark in color and wilted. However, this pod had the tallest plants. Additionally pod 45-48 was unable to be measured for cotyledon width, for no true leaves have sprouted yet. As related to my teammates' plants, mine were the second tallest. As for why I am unsure considering my pod was on the same water tray as the pod that didn't germinate quickly enough. I presume my seed size or fertilizer pellet was larger than the pod that didn't germinate as quickly.

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11/6/08

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Today we measured plant heights, and all of Kathryn's cotyledons have grown in. All the plant heights have increased by at least 2 mm within 2 days. 43 is now the tallest instead of 41 and 42. In fact, 42 is now the smallest.

Numbers 41 and 44 appeared dry or dehydrated, and the leaves were dark around the edges and veins.

Number 42 is the smallest plant and it is located right next to 43, the largest. Maybe 43 is hoarding nutrients from 42?

43 has another new true leaf with several buds.

11/10/08

	41	42	43	44
Plant Height (mm)	51	20	107	41
Number of Hairs on 1st True Leaf	5	6	21	4

Over four days, 43 more than tripled its height. 41 and 44 have over doubled their heights. As for 42, it only grew 4 mm. Excluding 42, the plants' growths seem to be exponential.

43 appears to be the strongest plant out of them all. It is the tallest, has the most true leaves (3), has the most yellow buds (17), and is just the biggest, in general. Additionally, 43 had the most leaf hairs. It had over 3 times as many hairs as any other plant. All other plants only had 2 true leaves and 2-7 yellow buds. Perhaps there is a correlation? However, the shortest plant has the second most hairs. Maybe leaf hair number is complexly inherited?

42 continues to be the smallest. 43's leaves were overshadowing 42 as a plant. I'm predicting that 43 is blocking sunlight for photosynthesis for 42. Also, 43 is a rather dark green. It can, therefore, absorb more light than the other plants to grow more.

44 has purple cotyledons. It may still be partially dehydrated.

11/12/08

	41	42	43	44
Plant Height (mm)	81	39	160	50
Number of Leaves (incl. cotyledons)	6	5	6	5
Bred for Most or Least Hairs	Least	Not breeding	Most	least
Number of Buds Pollinated	2	-	4	1

The plants all have increased their heights again over the past two days; the rate seems to be increasing. Instead of increasing about 30 mm (for 41 and 44) or 60 mm (43) in four days, they did that in just two. 42 made more progress than it had before.

The buds have blossomed today. 43 had 4, 42 had 1, 44 had 1, and 41 had 2. It seems that with a taller plant there are more blossoms.

Additionally, we counted the number of leaves today. Pretty much all the plants had the same amount of leaves regardless of other statistics. I wonder why? I would have presumed the most leaves with the tallest plant (most space for leaves).

Also today, we found out which plants are to be bred. The lowest leaf counts are being bred together and the highest leaf counts are being bred together. 43 was bred for the most hairs, 41 and 44 were bred for least hairs, and 42 was snipped. We pollinated our flowers with other flowers in the class using bees' bottoms on toothpicks.

11/14/08

Today we measured the plant heights and the heights to the first flower after the first round of pollination. Then, we pollinated any new buds that have opened. This is the last time that we will pollinate.

	41	42	43	44
Height to First Flower	62	-	71	40
Plant Height	102	-	194	50
# Buds Pollinated	1	-	5	1

One would think there is a correlation between plant height and number of buds available to pollinate. However, 41 is double the height of 44, and they both only had one bud to pollinate.

11/19/08

Today we counted the number of pods and blossoms. We also did a seed count estimate.

	41	42	43	44
# of Pods	4	-	15	1
# of Seeds (est)	17	-	90	3
# of Blossoms	5	-	9	2

Bruni mentioned a 2:1 ratio between pod number and blossoms. 44 followed that ratio, 43 was kind of close, but 41 did not support the ratio at all. 43 was bred for most hairs, and it had the largest data in all categories. Likewise, 41 and 44 were bred for least hairs, and they had the smallest data in all categories- perhaps a relationship? Does hair number have anything to do with other characteristics?

The leaves and blossoms are falling off now that all energy is being directed toward the pods and seeds.

Also, the pollen must have fallen on to closed buds, for 43 has more pods than flowers pollinated.

12/3/08

We cut the plants at the stems to dry today. Once they are dry, we can replant the seeds and form conclusions about our hypotheses and questions.

12/8/08

Today we counted the seed number and pod number for plants with least hairs. We then replanted the produced seeds. Our group planted seeds produced by least hair bred plants.

	44	78
# of pods	1	2
# of seeds	2	4

Compared to the rest of my group's data, 6 out of 9 of the plants had 0-5 seeds with 1 or 2 pods. Two plants had 14 and 23 seeds with 3 or 4 pods. Another plant had four pods with no seeds. There was quite a bit of variation among the seeds of the least hair plants. I expected a rather uniform outcome. I have begun to ponder whether hair number is a major factor in the number of seeds produced.

Also, the seeds themselves were varied in appearance. Most of the seeds were shades of brown, mostly a reddish brownish mahogany. However, a few seeds were green and misshapen and a few others were black. I wonder if seed color has anything to do with the fertility or success of survival of the next plant. What factors affect seed color?

12/12/08

Today we checked out the stem color of our new generation plants. All of my plants have purple stems. As a group, we had four green stems, 10 purple stems, and 2 DNGs. It appears that green stem color is a recessive trait. Our group predicts that the green stem also signals a short plant. However, I'm not sure that the results are completely genetic. The environment may have some part in phenotype. I'm wondering if the leaf hair number will have distinct differentiation between purple and green stems. Although, our group predicted that leaf hair number is a polygenic trait.

12/17/08

Today we measured the cotyledon widths of the plants.

	49	50	51	52
Cotyledon Width (mm)	15	9	13	11

Compared to the first round of fertilization, the cotyledon widths are consistently much larger. Our average means for our first generation were about 9.62 mm, whereas this round, the average is 11.43 mm. When we planted this time, we did a few adjustments for hydration and seed placement. Perhaps, the seeds were able to receive sunlight and stayed hydrated better allowing their success. We had less DNGs, as well (3 to 2). Overall, this generation seems to be a healthier or more successful generation.

12/23/08

Today we took the final leaf hair count for our F2 plants. Our group was studying the hair count when least hair F1 plants were bred together.

	49	50	51	52
Leaf Hair Count	19	6	70	69

It appears that the first true leaves of 51 and 52 had an odd amount of hairs, for the numbers were so high. It's also strange that 51 and 52 had so many leaf hairs when their parents had the least hairs. This makes me believe other factors, either genetic or environmental, affect the leaf hair number. I don't see it as a Mendelian trait.

Other observations I noticed were 52 and 51 had much larger first true leaves than 49 and 50, so it may be possible that there was more area for more plants hairs. Also, this generation, in general, had much darker leaves than the last generation. Maybe this is why they grew so much more successfully; they could attract more sunlight?

I noticed differences in cotyledons, as well. 52 and 50 had yellowish cotyledons; whereas, 51 and 49 had purplish cotyledons. 50's cotyledons were also extremely small. Perhaps 50 was robbed of nutrients or was planted in an inconvenient location for sunlight to prosper.

Kassy Fabbri

Background on Brassica rapa

What are Fast Plants®?

Fast Plants® (scientific name: *Brassica rapa*) are rapid-cycling brassicas. They are members of the crucifer family of plants, closely related to cabbage, turnips, broccoli and other cruciferous vegetables. Bred for over 30 years at the University of Wisconsin – Madison by Professor Paul H. Williams, Fast Plants® today require little more attention than continuous fluorescent light, water, and fertilizer. The seeds that you grow in your classroom can be immediately planted or stored for up to 10 years in a refrigerator.

The entire life cycle for Fast Plants® is extremely short, and under ideal growing conditions of continuous light, water, and nutrition, plants will produce harvestable seeds approximately 40 days after planting.

Day 5 = cotyledons
Day 7 = first true leaves
Day 11 = buds
Day 13 = blossoms
Day 18 = pods
Day 28 = no blossoms, just pods

Brassica rapa is part of the family of cruciferous plants (a large group of plants that includes mustard, radish, cabbage, broccoli, kohlrabi, and more).
It's part of the family Cruciferae.

Four Easy Steps for Growing Successful Wisconsin Fast Plants®:

1. Continuous Fluorescent Light
2. Continuous Water and Fertilizer
3. Consistent Room Temperature
4. Potting Mix rather than a heavy "soil."

Citation:

Fast Plants. 2007. Ed. Paul Williams. University of Wisconsin-Madison. 6 Jan. 2009. <http://www.fastplants.org>.

Brassica rapa can self pollinate.

Citation:

"Actin Dynamics in Papilla Cells of Brassica rapa during Self- and Cross-pollination." Plant Physiology. 2007. America Society of Plant Biologists. 6 Jan. 2009. <http ://www.plantphysiol.org/cgi/content/abstract/pp.106.095273v1>.

PlantingScience Portfolio

Rebecca Brewer (Johns)
Troy High School

PlantingScience Portfolio-Rebecca Brewer (Johns)

Teacher Profile

I am currently in my 10th year as a high school biology teacher at Troy High School; a suburban school district located in Troy, Michigan. For the majority of my career I have taught Advanced Placement Biology and honors ninth grade biology. However, this past year I also taught one section of ninth grade biology to at-risk students for the first time.

I attended Michigan State University where I received my Bachelors of Science in Biology, with minors in Chemistry and French, along with a teaching certificate. I went on to receive my Masters of Arts also from Michigan State University in Curriculum and Teaching. While at Michigan State, I was a teaching assistant for two different biology laboratory courses and for a genetics lecture course.

Over the years I have held 30+ education-related jobs which include everything from writing a nation-wide on-line AP Biology course, to teaching science summer camps, to running sky talks at a planetarium, to writing questions for a nation-wide biology educators' exam, etc. Currently I am working towards my Masters +30, which is the highest step in the Troy School District and I am busy writing an inquiry-based biology laboratory manual for a textbook publisher.

Some achievements I am most proud of in the past ten years as an educator include: having MIT name a minor planet after me when two former students who placed in the Siemens-Westinghouse Competition nominated me as their "most influential teacher" (2006), receiving the title of one of the top 20 educators in the nation according to USA Today (2007), having Oprah Winfrey's Educational Division contact me to apply to go teach at her school in South Africa (2007), and most recently being named the 2008 Outstanding Biology Teacher for Michigan. I am also very active in getting students involved in biology-related competitions and have helped students to accomplish the following: Grand Prize Winners for NASA's Hypergravity Competition (2005), Toshiba's Exploravision Regional Winner (2006), and Intel's International Science and Engineering Fair Grand Prize Winner (2006).

Currently, my professional efforts have been focused on creating an opportunity for my students to conduct summer research at Henry Ford Hospital in Detroit, I am acting as director for selecting the next recipient of the National Association of Biology Teachers' Outstanding Biology Teacher Award for Michigan, and I am preparing to teach a CollegeBoard one-week workshop to new AP Biology teachers this upcoming summer.

In my classroom, I utilize a variety of teaching strategies in order to make biology instruction applicable to the lives of my students. I strive to maintain structure in creating a daily routine such as starting the class with an opener (video clip, journal entry, etc.) to hook their interests, writing specific essential questions on the board daily that are aligned with the state curriculum, and providing opportunities for my classes to *discover* biological principles. I am a strong advocate for "Learning by Design" and promote inquiry-based instruction in the classroom. This transition in my teaching style came after I enrolled in an inquiry-teaching graduate course one year ago and after I visited a high school in Michigan that operates their biology program through case-based inquiry investigations. I have found that by revamping my instructional methods to encompass this 'backwards design" it has allowed my classes to utilize more higher-level reasoning and in effect, more active learning is taking place in my classroom.

I also am a strong advocate of utilizing many visual displays in my teaching to bring microscopic, detailed concepts to the forefront of the classroom. My students jokingly call me "Mrs. Frizzle" from the Magic School Bus because of my tendency to "jump into" micro-level processes when I teach. Over the years I have created many models including a 6 foot long walk-through digestive tract which we named "Hungry Jack", interactive foam models of the four nutrient cycles where the students themselves become the nutrients (water, carbon, nitrogen, and phosphorus), and a 3-D demonstration of how Dolly the first cloned mammal was created from conception to a "live" birth (stuffed toy sheep that gives birth and baas ☺) to name a few examples.

I chose to implement the PlantingScience program in my classroom because I am always looking for new ways to get my students performing inquiry. Presently, I mostly do guided inquiry and I wanted to expand into having my classes carry out open inquiry investigations. I chose to conduct PS with my at-risk ninth graders because their schedule is more flexible than AP Biology and I was told this past summer at Texas A&M by several teachers in attendance that low-level students get the most out of hands-on investigations. I also only have one section of 9th graders, while I have four sections of AP juniors and seniors. So I thought it would be more manageable to implement PS with one section of students versus four seeing that this is the first time I attempted open inquiry let alone working with mentor scientists on-line in the classroom.

School and Class Profile

Troy High School is a public school located in Oakland County in the suburbs of Southeastern Michigan. The student body is composed of 2,089 students in grades 9th through 12th. The breakdown of ethnicities includes: 1,463 White, 523 Asian, 68 Black, 28 Hispanic, and 7 American Indian. A total of 39 students are eligible for free lunches, while 20 students receive reduced-lunch prices. The most recent change to the district is a result of the struggling automotive industry and numerous businesses and schools closing in Michigan. Consequently, Troy and the surrounding suburbs are experiencing an increased number of inner-city families moving to the suburbs / a large influx of at-risk students changing the climate of the student body. As a result, suspensions are at an all time high and behavioral problems are a constant issue in low-level courses. The district is adapting to this change and trying to acclimate the new students to Troy's expectations for both course rigor and to reinforce appropriate behavior in a school setting. Class sizes in all science courses are capped at 24 students. I presently have 22 students in my 9th grade biology course and no more than 20 students in each section of my four sections of AP Biology.

Student Work

My 9th graders implemented PlantingScience and consisted of 5 different group projects. The questions they investigated were:

1) Does seed size affect the germination rate of 3 types of seeds?
2) Which fertilizer brand allows red clover seeds to germinate the quickest?
3) Does the water source affect the growth rate of sunflower seeds?
4) How does the color of light affect green beans seeds germination and growth?
5) Does alfalfa grow in burnt soil?

Included in this section are: A) Pictures of students at work, along with their data, results, and experimental design, B) Planning guides that the students completed to show where they started / changes that occurred during the 3 week period, C) Written reflections from students and how they felt about being mentored by a scientist, and D) My reflection on the student's attitudinal change and content knowledge gains as a result of participation in PS.

A) Pictures of students at work, along with their data, results, and experimental design.

<u>"The Muffin People"- Does seed size affect the germination rate of 3 types of seeds?</u>

This group found that the smallest seeds (the alfalfa) germinated the quickest.

Large Seeds- Green Bean (growth of stems in millimeters)

Date	Seed 1	Seed 2	Seed 3	Seed 4	Seed 5
3-24-09	0	0	0	0	0
3-25-09	0	0	0	0	0
3-26-09	2	3	0	0	0
3-27-09	15	17	0	0	0
3-30-09	32	40	0	0	0
3-31-09	33	42	0	0	0
4-01-09	33	44	0	0	0
4-02-09	33	45	0	0	0

Medium Seeds- Sunflower (growth of stems in millimeters)

Date	Seed 1	Seed 2	Seed 3	Seed 4	Seed 5
3-24-09	0	0	0	0	0
3-25-09	0	0	0	0	0
3-26-09	0	0	0	0	0
3-27-09	0	0	0	0	0
3-30-09	2	0	25	0	0
3-31-09	25	0	43	0	0
4-01-09	41	0	67	0	0
4-02-09	72	0	97	0	0

Small Seeds- Alfalfa (growth of stems in millimeters)

Date	Seed 1	Seed 2	Seed 3	Seed 4	Seed 5
3-24-09	0	0	0	0	0
3-25-09	0	0	0	0	0
3-26-09	0	0	0	0	0
3-27-09	0	0	0	0	0
3-30-09	0	0	0	0	2
3-31-09	0	10	0	0	5
4-01-09	0	40	0	0	15
4-02-09	0	53	0	0	23

"The Show Stoppers"- Which fertilizer brand allows red clover seeds to germinate the quickest?

This group found that the only fertilizer that produced any results was the Tetra Floral Pride brand fertilizer. They only got growth with this fertilizer and no growth with Schultz brand fertilizer or water. They think the reason for the poor results was they were either too close to the light bank and/or not enough water was given to all the seeds.

Water / Control Group- Red Clover (growth of stems in millimeters)

Date:	1st group of 3	2nd group of 3	3rd group of 3	4th group of 3	5th group of 3	6th group of 3	7th group of 3	8th group of 3	9th group of 3
3-24-09	0	0	0	0	0	0	0	0	0
3-25-09	0	0	0	0	0	0	0	0	0
3-26-09	0	0	0	0	0	0	0	0	0
3-27-09	0	0	0	0	0	0	0	0	0
3-30-09	0	0	0	0	0	0	0	0	0
3-31-09	0	0	0	0	0	0	0	0	0
4-01-09	0	0	0	0	0	0	0	0	0
4-02-09	0	0	0	0	0	0	0	0	0

Schultz Brand Fertilizer- Red Clover (growth of stems in millimeters)

Date:	1st group of 3	2nd group of 3	3rd group of 3	4th group of 3	5th group of 3	6th group of 3	7th group of 3	8th group of 3	9th group of 3
3-24-09	0	0	0	0	0	0	0	0	0
3-25-09	0	0	0	0	0	0	0	0	0
3-26-09	0	0	0	0	0	0	0	0	0
3-27-09	0	0	0	0	0	0	0	0	0
3-30-09	0	0	0	0	0	0	0	0	0
3-31-09	0	0	0	0	0	0	0	0	0
4-01-09	0	0	0	0	0	0	0	0	0
4-02-09	0	0	0	0	0	0	0	0	0

Tetra Brand Fertilizer- Red Clover (growth of stems in millimeters)

Date:	1st group of 3	2nd group of 3	3rd group of 3	4th group of 3	5th group of 3	6th group of 3	7th group of 3	8th group of 3	9th group of 3
3-24-09	0	0	0	0	0	0	0	0	0
3-25-09	0	0	0	0	0	0	0	0	0
3-26-09	0	5	0	0	0	0	0	0	0
3-27-09	0	5	0	0	0	0	0	0	0
3-30-09	16	16	0	0	0	0	0	0	0
3-31-09	16	16	0	0	0	0	0	0	0
4-01-09	16	died	0	0	0	0	0	0	0
4-02-09	died	died	0	0	0	0	0	0	0

"Tropic Thunder"- Does the water source affect the growth rate of sunflower seeds?

This group found that tap water was the best at promoting root growth, but they got very little stem growth. In retrospect, they wished they had focused on root growth the entire time and/or hadn't put their seeds in water dishes.

Spring Water- Sunflowers (growth of stems in millimeters)

Date	Seed # 1	Seed # 2	Seed # 3	Seed # 4	Seed # 5	Seed # 6	Seed # 7	Seed # 8	Seed # 9	Seed # 10
3-24-09	0	0	0	0	0	0	0	0	0	0
3-25-09	0	0	0	0	0	0	0	0	0	0
3-26-09	0	0	0	0	0	0	0	0	0	0
3-27-09	0	0	0	0	0	0	0	0	0	0
3-30-09	0	0	0	0	0	0	0	0	0	0
3-31-09	0	0	0	0	0	0	0	0	0	0
4-01-09	0	0	0	0	0	0	0	0	0	0
4-02-09	0	0	0	0	0	0	0	0	0	0

Additional Observations:
While we chose to measure the stems of the seeds, we have noticed that the roots are all growing for each of the 3 treatments.
Root growth for spring water on 3/27 = 60 mm.
Root growth for spring water on 3/30 = 80 mm.
Root growth for spring water on 3/31 = 160 mm.
Root growth for spring water on 4/1 = 170 mm.
Root growth for spring water on 4/2 = 180 mm

Tap Water- Sunflowers (growth of stems in millimeters)

Date	Seed # 1	Seed # 2	Seed # 3	Seed # 4	Seed # 5	Seed # 6	Seed # 7	Seed # 8	Seed # 9	Seed # 10
3-24-09	0	0	0	0	0	0	0	0	0	0
3-25-09	0	0	0	0	0	0	0	0	0	0
3-26-09	0	0	0	0	0	0	0	0	0	0
3-27-09	0	0	0	0	0	0	0	0	0	0
3-30-09	0	0	8	0	0	0	0	0	0	0
3-31-09	0	0	45	0	0	0	0	0	0	0
4-01-09	0	0	75	0	0	0	0	0	0	0
4-02-09	0	0	85	0	0	0	0	0	0	0

Additional Observations:
Root growth for tap water on 3/27 = 70 mm.
Root growth for tap water on 3/30 = 110 mm.
Root growth for tap water on 3/31 = 120 mm.
Root growth for tap water on 4/1 = 175 mm.
Root growth for tap water on 4/2 = 180 mm.

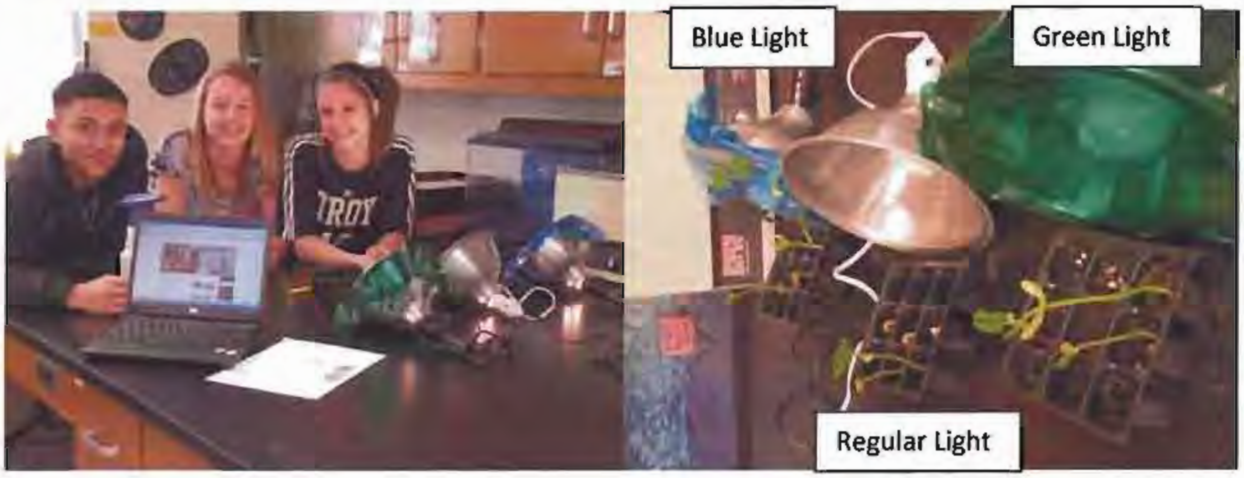
Toilet Water- Sunflowers (growth of stems in millimeters)

Date	Seed # 1	Seed # 2	Seed # 3	Seed # 4	Seed # 5	Seed # 6	Seed # 7	Seed # 8	Seed # 9	Seed # 10
3-24-09	0	0	0	0	0	0	0	0	0	0
3-25-09	0	0	0	0	0	0	0	0	0	0
3-26-09	0	0	0	0	0	0	0	0	0	0
3-27-09	0	0	0	0	0	0	0	0	0	0
3-30-09	0	0	0	0	0	0	0	0	0	0
3-31-09	0	0	0	0	0	0	0	0	0	0
4-01-09	0	0	0	0	0	0	0	0	0	0
4-02-09	0	0	0	0	0	0	0	0	0	0

Additional Observations:

Root growth for toilet water on 3/27 = 85 mm.
Root growth for toilet water on 3/30 = 80 mm.
Root growth for toilet water on 3/31 = 90 mm.
Root growth for toilet water on 4/1 = 100 mm.

<u>"Seed Unit"- How does the color of light affect green beans seeds germination and growth?</u>



This group found that green beans grew the best in blue light. They did not however measure the amount of water given to the seeds each day, so their results might not be accurate. They also did not understand why blue light promoted the most growth. If there was time, they probably should have ran their experiment a second time.

Regular Light- Green Bean (stem growth in millimeters)

Date	Seed #1	Seed #2	Seed #3	Seed #4	Seed #5	Seed #6	Seed #7	Seed #8	Seed #9
3-24-09	0	0	0	0	0	0	0	0	0
3-25-09	0	0	0	0	0	0	0	0	0
3-26-09	0	0	0	0	0	0	0	0	0
3-27-09	0	0	0	0	0	0	0	0	0
3-30-09	25	0	3	5	0	0	0	0	0
3-31-09	60	0	3	20	0	0	0	0	0
4-01-09	100	0	3	30	0	0	0	10	0
4-02-09	160	0	3	95	5	0	0	50	0

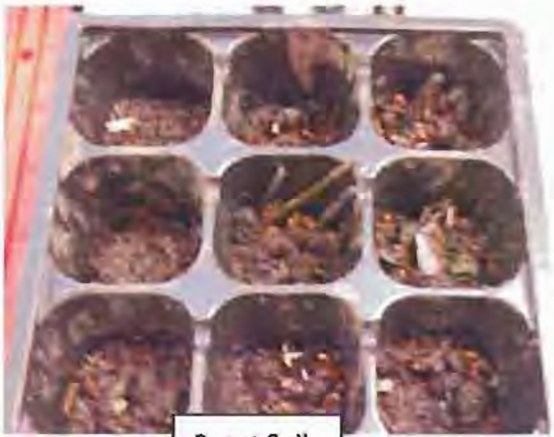
Blue Light- Green Bean (stem growth in millimeters)

Date	Seed #1	Seed #2	Seed #3	Seed #4	Seed #5	Seed #6	Seed #7	Seed #8	Seed #9
3-24-09	0	0	0	0	0	0	0	0	0
3-25-09	0	0	0	0	0	0	0	0	0
3-26-09	0	0	0	0	0	0	0	0	0
3-27-09	0	0	0	0	0	0	0	0	0
3-30-09	5	65	0	0	0	0	0	35	0
3-31-09	15	145	0	5	0	0	0	40	3
4-01-09	30	190	0	20	0	0	0	85	4
4-02-09	70	225	0	45	0	0	0	130	10

Green Light- Green Bean (stem growth in millimeters)

Date	Seed #1	Seed #2	Seed #3	Seed #4	Seed #5	Seed #6	Seed #7	Seed #8	Seed #9
3-24-09	0	0	0	0	0	0	0	0	0
3-25-09	0	0	0	0	0	0	0	0	0
3-26-09	0	0	0	0	0	0	0	0	0
3-27-09	0	0	0	0	0	0	0	0	0
3-30-09	0	0	0	0	0	6	0	3	20
3-31-09	0	0	0	0	0	40	0	3	55
4-01-09	0	0	0	0	0	100	0	3	140
4-02-09	0	0	0	0	0	130	0	10	190

<u>"Rose Bowl"- Does alfalfa grow in burnt soil?</u>



Burnt Soil

Regular Soil

This group found that alfalfa grew best in normal soil, not burnt soil.

Regular Soil- Alfalfa (growth of stems in millimeters)

Date	1st group of 10	2nd group of 10	3rd group of 10	4th group of 10	5th group of 10	6th group of 10	7th group of 10	8th group of 10	9th group of 10
3-24-09	0	0	0	0	0	0	0	0	0
3-25-09	10	10	10	10	10	10	10	10	10
3-26-09	11	11	10.7	10.2	11	10.7	10.7	10.7	11
3-27-09	12	12	11	10.5	12	11	11	11	14.5
3-30-09	20	38	30	40	20	20	30	30	30
3-31-09	40	39	40	40	35	40	39	30	30
4-01-09	41	39	43	49	35	45	40	39	31
4-02-09	42	40	40	47	4-	47	40	40	31

Burnt Soil- Alfalfa (growth of stems in millimeters)

Date	1st group of 10	2nd group of 10	3rd group of 10	4th group of 10	5th group of 10	6th group of 10	7th group of 10	8th group of 10	9th group of 10
3-24-09	0	0	0	0	0	0	0	0	0
3-25-09	0	0	0	0	0	0	0	0	0
3-26-09	0	0	0	0	1	2	0	1	1
3-27-09	0	0	0	0	2	3	0	2	2
3-30-09	0	0	0	0	10	8	1	15	10
3-31-09	1	0	0	2	20	30	10	20	10
4-01-09	0	0	0	4	29	38	26	30	26
4-02-09	4	0	0	9	33	40	30	20	28

B) Planning guides that the students completed to show where they started / changes that occurred during the 3 week period. (See part C to see changes that occurred)

Planting Science

Your Group's Name: The muffin people
Date: March 23, 2009

1. What is your research question?
Does seed size affect germination rate of three different seeds.

2. What is your hypothesis? (Written as "If...then...because")
If you give small alfalfa, green bean and medium sunflower seeds equal amounts of water, light, and soil then it will take longer for the radish and sunflower seeds because they are bigger and need more.

3. What is the one variable you are testing in your experiment?
seed size

4. What is the control group you are testing in your experiment?
none

5. Recall the equation for photosynthesis is:

$$6CO_2 + 6\,H_2O + light \rightarrow 6O_2 + C_6H_{12}O_6$$

Therefore, what does every seed / plant need to grow?
carbon dioxide, water, light, oxygen, and sugar

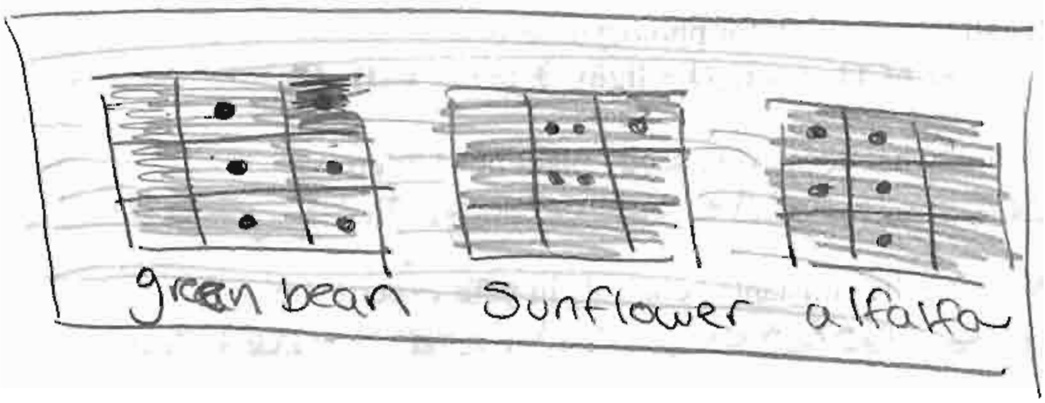
6. What are the constants / controls in your experiment?
same water, soil, containers, and light.

7. What do you think is going to occur in your experiment?
I think they will sprout in this order alfalfa, sunflower, grean bean.

8. What type of seeds are you going to use in your experiment?
alfalfa, sunflower, green bean

9. How many seeds are you going to plant in your experiment?
For example, 10 seeds in sunlight and 10 seeds in darkness.
Five seeds.

10. Draw a picture of your experimental design in the space below. Be sure to label everything.



Planting Science

Your Group's Name: The Showstoppers
Date: March 23, 2009

1. What is your research question?
Which fertilizer brand allows red clover seeds to germinate the quickest.

2. What is your hypothesis? (Written as "If…then…because")
If I fertilize the red clovers with a certain fertilizer and one without any fertilizer one will grow faster than another.

3. What is the one variable you are testing in your experiment?
red clover, fertilizer

4. What is the control group you are testing in your experiment?
the red clover w/out fertilizer

5. Recall the equation for photosynthesis is:

$$6CO_2 + 6\ H_2O + light \rightarrow 6O_2 + C_6H_{12}O_6$$

Therefore, what does every seed / plant need to grow?
light, water

6. What are the constants / controls in your experiment?
the fertilizer

7. What do you think is going to occur in your experiment?
The red clovers w/ fertilizer

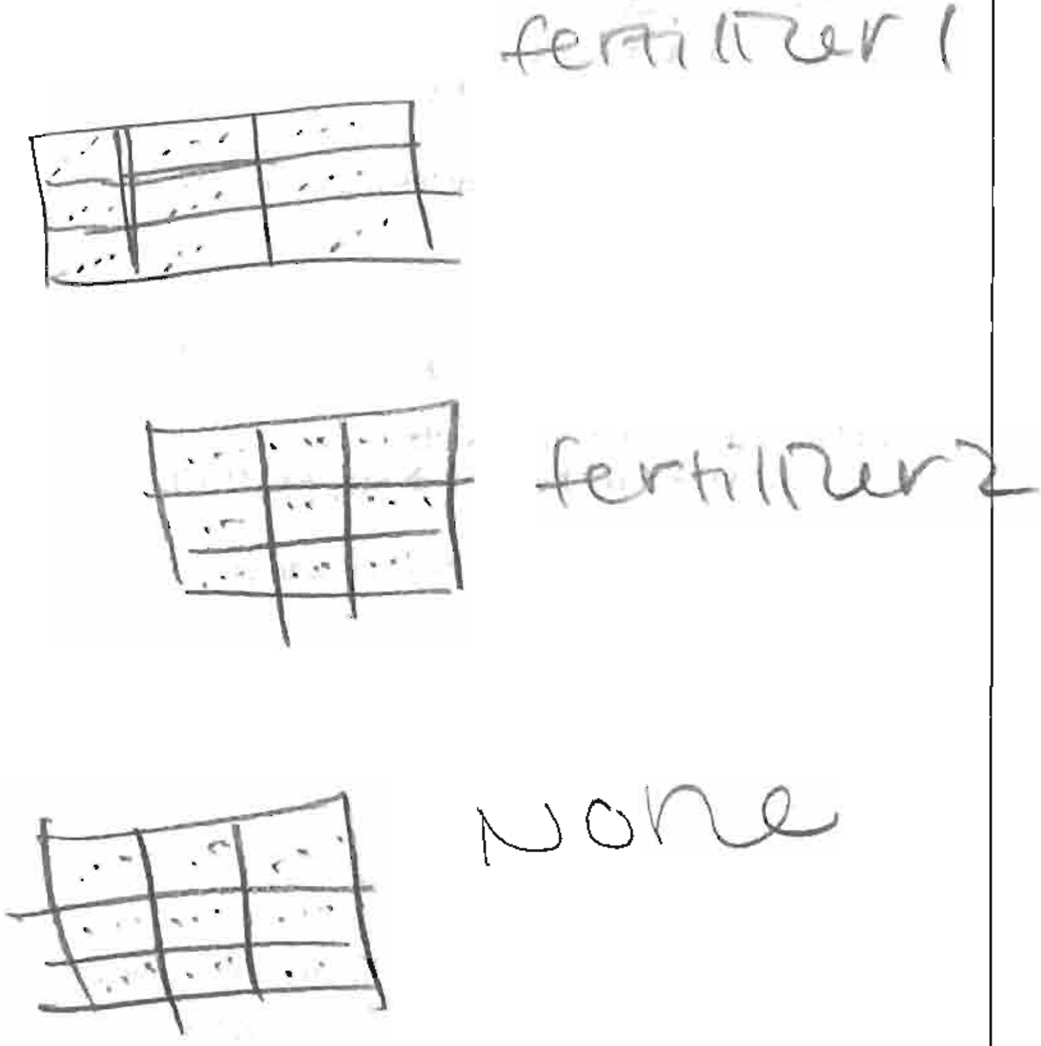
8. What type of seeds are you going to use in your experiment?

red clover

9. How many seeds are you going to plant in your experiment?
For example, 10 seeds in sunlight and 10 seeds in darkness.

3 in each

10. Draw a picture of your experimental design in the space below. Be sure to label everything.



Planting Science

Your Group's Name: Tropic Thunder
Date: March 23, 2009

1. What is your research question?
Does the water source affect the growth of sunflower seeds.

2. What is your hypothesis? (Written as "If…then…because")
If we put spring water it will grow faster because it is natural and clean.

3. What is the one variable you are testing in your experiment?
Bottled water

4. What is the control group you are testing in your experiment?
No water

5. Recall the equation for photosynthesis is:

$$6CO_2 + 6\ H_2O + \text{light} \rightarrow 6O_2 + C_6H_{12}O_6$$

Therefore, what does every seed / plant need to grow?
A sunflower

6. What are the constants / controls in your experiment?
The control group is tap water.

7. What do you think is going to occur in your experiment?
I think that the spring water is going to be good.

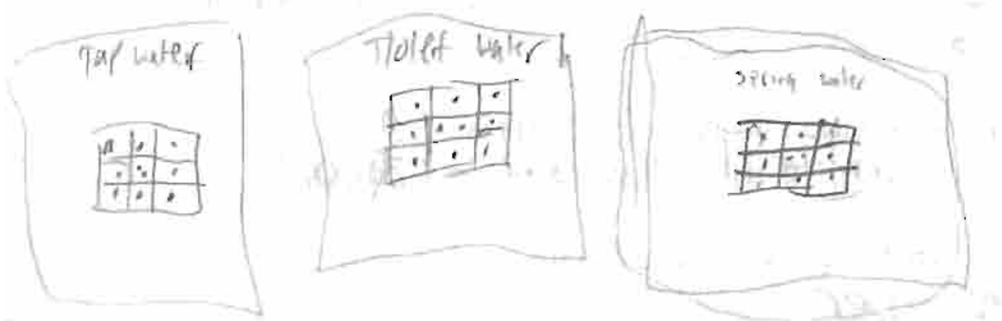
8. What type of seeds are you going to use in your experiment?

SUN Flower

9. How many seeds are you going to plant in your experiment?
For example, 10 seeds in sunlight and 10 seeds in darkness.

10 seeDS For eACh TYPe OF WAter.

10. Draw a picture of your experimental design in the space below. Be sure to label everything.



Planting Science

Your Group's Name: Seed - unit
Date: March 23, 2009

1. What is your research question?
How does the color of light affect green beans seeds germination and growth?

2. What is your hypothesis? (Written as "If…then…because")
If green beans are exposed to different colored lights then they will grow at different rates because of the different colored lights.

3. What is the one variable you are testing in your experiment?
light color

4. What is the control group you are testing in your experiment?
colored light

5. Recall the equation for photosynthesis is:

$$6CO_2 + 6\ H_2O + \text{light} \rightarrow 6O_2 + C_6H_{12}O_6$$

Therefore, what does every seed / plant need to grow?
water, light, O_2

6. What are the constants / controls in your experiment?
The controls in our experiment are the different colors of light. Blue and green

7. What do you think is going to occur in your experiment?
I think with the normal light it will grow faster and with the colored light it will grow slower.

8. What <u>type of seeds</u> are you going to use in your experiment?

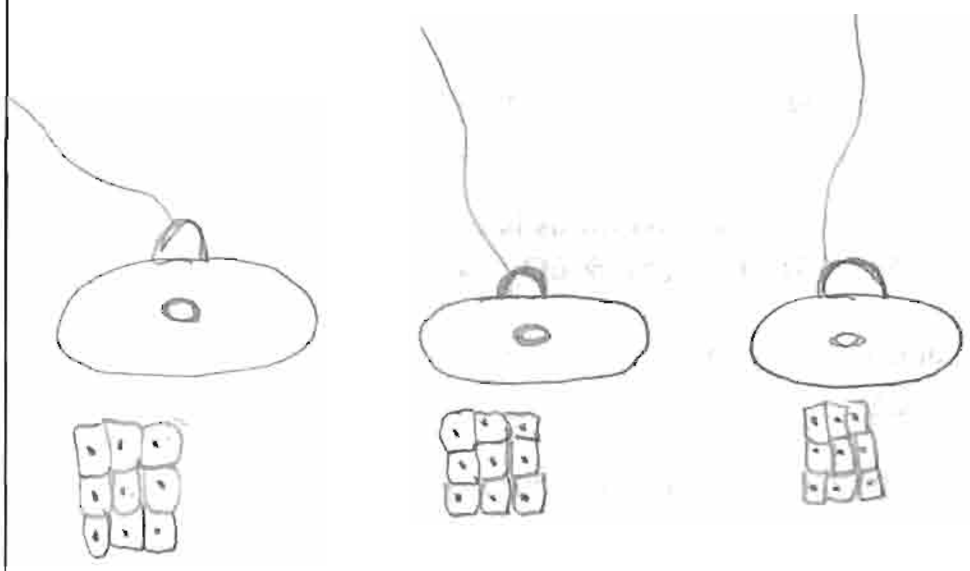
green beans

9. How <u>many</u> seeds are you going to plant in your experiment?

**For example, 10 seeds in sunlight and 10 seeds in darkness.*

9 seeds in regular light, 9 seeds in green light, and 9 seeds in blue light.

10. Draw a picture of your <u>experimental design</u> in the space below. Be sure to label everything.



Planting Science

Your Group's Name: Rose Bowl
Date: March 23, 2009

1. What is your research question?
Do alfalfa seeds grow in burnt soil.

2. What is your hypothesis? (Written as "If…then…because")
If we burn alfalfa then the seeds will not grow because the soil has better nutritions.

3. What is the one variable you are testing in your experiment?
the Alfalfa

4. What is the control group you are testing in your experiment?
the burnt soil

5. Recall the equation for photosynthesis is:

$$6CO_2 + 6\ H_2O + light \rightarrow 6O_2 + C_6H_{12}O_6$$

Therefore, what does every seed / plant need to grow?
CO2, H2O, light, O2, Glucose

6. What are the constants / controls in your experiment?
Burnt soil & normal soil.

7. What do you think is going to occur in your experiment?
the Alfalfa

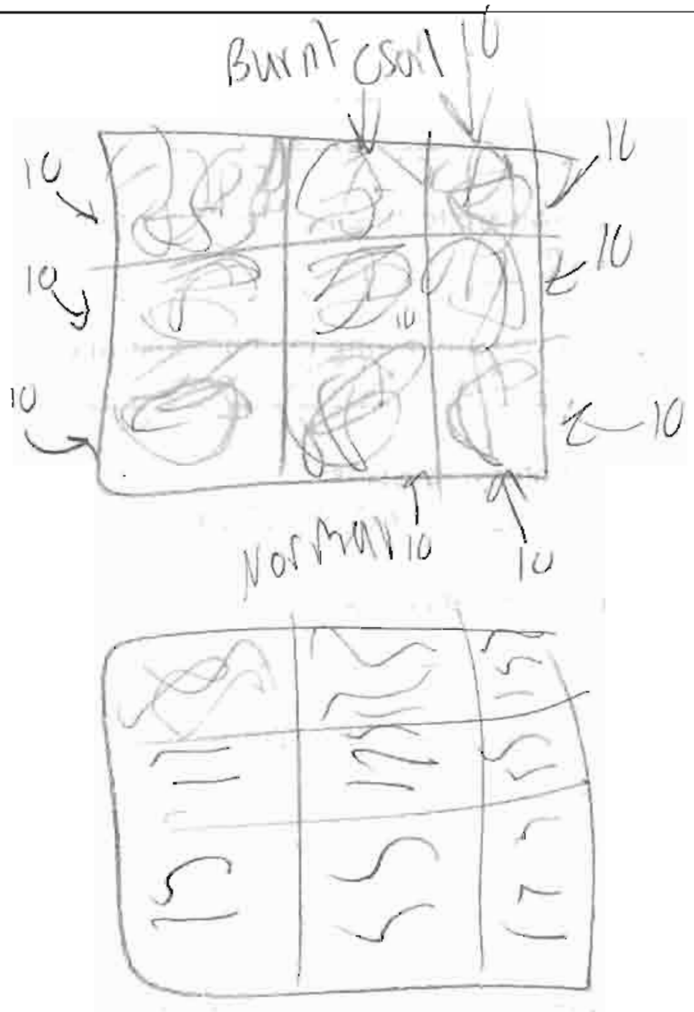
8. What type of seeds are you going to use in your experiment?

Alfalfa

9. How many seeds are you going to plant in your experiment?
For example, 10 seeds in sunlight and 10 seeds in darkness.

10 Seeds per Dish

10. Draw a picture of your experimental design in the space below. Be sure to label everything.



C) Written reflections from students and how they felt about being mentored by a scientist.

Planting Science Final Thoughts

Your Name: vinceena vang
Your Group's Name: The Show stoppers

1. What was your group testing?

If we used a fertilizer then which would germinate faster?

2. What can you conclude about your experiment?

Tetra Floride was the best fertilizer for red clovers.

3. What mistakes (if any) did your group make during this experiment?

TOO much light, or not enough water for red clovers.

4. How do you feel about being mentored by a scientist?

Cool, because they are sharing their knowledge of light on us and guiding us toward the right direction; wish there was more interaction.

Experiment Overview:

1. What is the control group in an experiment?

"Natural circumstances" how it would be normally, used for comparison.

2. What is the variable in an experiment?

what "varies" in an experiment

3. How many variables are in an experiment?

one

4. Why is it important to only have 1 variable in an experiment? so you can tell how the one variable is affecting the result

5. What do seeds need to germinate?

water and light

6. Where do seeds get their energy from?

The sugar surrounding "baby plant" inside the seed.

Planting Science Final Thoughts

Your Name: Lexi Hutchinson
Your Group's Name: The muffin people

1. What was your group testing?
how seed size affects growth.

2. What can you conclude about your experiment?
We can conclude that the alfalfa seeds germinated first, then sunflower, and green beans.

3. What mistakes (if any) did your group make during this experiment?
We used 2 variables, seed size and seed type

4. How do you feel about being mentored by a scientist?
I wished their could have been more interaction with the scientist

Experiment Overview:

1. What is the control group in an experiment?
"Natural circumstances," how it would be normally. Used for comparison.

2. What is the variable in an experiment?
What "varies" in an experiment.

3. How many variables are in an experiment?
1 (one)

4. Why is it important to only have 1 variable in an experiment? So you can tell how the one variable is affecting the results

5. What do seeds need to germinate?
Water and light

6. Where do seeds get their energy from?
The sugar surrounding the "baby plant" inside the seed.

Planting Science Final Thoughts

Your Name: Larry Joseph Sylvester
Your Group's Name: Tropic Thunder

1. What was your group testing?
What water grows plants the fastest.

2. What can you conclude about your experiment?
That tap water was the best because toilet and spring didn't grow at all.

3. What mistakes (if any) did your group make during this experiment?
We did not water the plants well enough.

4. How do you feel about being mentored by a scientist?
It felt pretty cool because she told how to grow plants well.

Experiment Overview:

1. What is the control group in an experiment?
"Natural circumstances," how it would be normally. Used for Comparison.

2. What is the variable in an experiment?
what "varies" in an experiment.

3. How many variables are in an experiment?

One

4. Why is it important to only have 1 variable in an experiment? So you can tell how the one variable is affecting the results.

5. What do seeds need to germinate?

H_2O + Lights

6. Where do seeds get their energy from?
The sugar surrounding the baby plant around the seed.

D) My reflection on the student's attitudinal change and content knowledge gains as a result of participation in PS.

In conducting PlantingScience with my 9th graders, I saw several students' attitudes toward scientific investigations change over the course of the three-week unit. The students enjoyed going onto the computers each day and were excited to see growth from their seeds. I think open-ended investigations such as the ones provided by PS are great because they reinforce the scientific method and the students take ownership of their experiments because they themselves designed them. It was not uncommon to see groups eagerly checking out their plants each day as they walked into the classroom and many of the students enthusiastically took their plants home to show their parents at the conclusion of the experiments. Without a doubt PS allowed students to see that science is hands-on, engaging, and is about manipulating a variable to answer a question they have about the world around them.

As for content knowledge, if you look at Part B (Planning guides that the students completed to show where they started / changes that occurred during the 3 week period) and the post-test I gave my students which is found on the back side of Part C (Written reflections from students and how they felt about being mentored by a scientist), it is evident that my students got a thorough review of the scientific method. My students now recall what they learned in the first unit of the year regarding the scientific method- that only 1 variable can be manipulated in an experiment, what a variable is, and what a control group is. They also gained an understanding of what it takes to get a seed to germinate and where seeds get their energy to grow from. I also saw that most of my students scored better on the online PS post-test than the pre-test, which also reconfirms that both working with a mentor scientist online and conducting hands-on open-ended investigations is beneficial to increasing student understanding of the content.

Classroom Context

Planting Science was conducted over three weeks during the second period of the school day from 8:31-9:31 AM (a 60 minute course). However, the amount of time devoted to PS each day varied depending upon which stage of the research the students were at. The students worked on PS only during class time and not from their personal home computers. The schedule below reflects what occurred during this three-week period.

Monday, 3/9/09	Students activated their accounts by logging into the PS website. Fourteen students logged in, but only 7 could get the pre-test to open (problems with the website). Some students were absent and will take the pre-test when they return.
Tuesday, 3/10/09	No School (state testing).
Wednesday, 3/11/09	Half-day (state testing). I didn't see my 9th graders today.
Thursday, 3/12/09	The students developed a research question to investigate.
Friday, 3/13/09	Tried to work on PS, but the internet was not working on the wireless laptops. So I had the students chose their group names to at least accomplish something during the period.
Sunday, 3/15/09	I logged into PS over the weekend to add the group names the students chose on Friday. I also selected Google images for each group to allow us to move forward in PS on Monday.
Monday, 3/16/09	Once again, the internet was down on the wireless laptops. I contacted the Technology Department for our district and they are looking into fixing the problem.
Tuesday, 3/17/09	Wireless laptops are down again. I have 4 students suspended, 3 out of class for ESL testing, and one on vacation. So today would have been difficult to work on PS anyways.
Wednesday, 3/18/09	I decided to take the students to the computer lab to take the pre-test, say "hello" to their mentor scientists, to post their investigative questions, and to list the supplies needed to conduct their research projects. I also wrote the mentors to introduce my 9th grade class to them and thank them for volunteering their time.
Thursday, 3/19/09	Half-day so I did not see my 9th graders.
Friday, 3/20/09	Absent students said "hello" to their mentors, students elaborated on their research ideas, and some students responded to their mentor scientists' questions.

Monday, 3/23/09	Students filled out a planning sheet I developed so I could see their experimental design before starting their actual projects. I then approved their designs during the hour and/or helped them improve them if necessary.
Tuesday, 3/24/09	The students planted their seeds today / set up their experiments. They also wrote their mentor scientists.
Wednesday, 3/25/09	Students took their first measurements.
Thursday, 3/26/09	Students recorded growth data. We saw that only two groups had growth by the second day and both groups had used alfalfa seeds.
Friday, 3/27/09	Students uploaded their data sheets for the week for their mentor scientists to see the results so far, they continued to collect data, and watered their plants for the weekend.
Monday, 3/30/09	Students continued to collect data and communicate with mentor scientists.
Tuesday, 3/31/09	Students continued to collect data and communicate with mentor scientists.
Wednesday, 4/1/09	Students continued to collect data and communicate with mentor scientists.
Thursday, 4/2/09	Students continued to collect data and communicate with mentor scientists. They also took the post-test and an in-class quiz I developed.

To prepare my students for PS, I had my classes perform inquiry-based investigations all year long. We started the school year out by doing the "Corn Growing Contest" on the first day of class that Claire gave us this past summer. For many of my students this was their very first exposure to growing a plant from seed. I also did approximately one inquiry-based lab per unit throughout the school year. Some examples included: designing a lab to test for pill bug preferences, another to test for factors that affect enzyme function, and another that tested different fruits for DNA quantities, etc. However, as I mentioned earlier, all these labs were "guided inquiry" and not "open inquiry" like PS.

Also, to help my students come up with a question to investigate in PS, I created a list of possible research questions. I had a list of 12 questions to choose from and included options such as: Does salinity affect the germination and growth of seeds?; Does the pH of water affect the germination and growth of seeds?; Does freezing seeds for various intervals affects the germination and growth of seeds?; etc.

The content area that PS covered was the scientific method. Teachers often just teach the scientific method during the first unit of the school year and never again. PS was a wonderful opportunity to reinforce the scientific method, which after all are the basic principles that guide all scientific investigations. PS also fell during the classification unit, so I used this an avenue to expand upon what they learning regarding how plants are classified as well. I never had students grow plants during the classification unit in the past, so I really liked the hands-on addition of PS to this unit of the course.

Unfortunately, I did encounter several challenges while conducting PS with my 9th graders. Being that I am new to teaching low-level students, this year in general has been difficult for me to adjust to this type of student. Often I would tell a group or an individual student to take the pre-test or post-test, or to write their scientist, or to water their seeds, or to record their data and the student did not follow through on my request. What made this so difficult was that each student and/or group was at a different point in the process for a variety of reasons- suspensions, skipping class, vacation, etc. that it was hard to give general directions to the entire class. So I solved this problem by creating small daily reminder sheets for each student to get them to the next step. This was a lot of work on my part to individually track where each student was at and in the future I would not conduct PS with a low-level group. I know others have had success with at-risk students, but I found it was an uphill battle to keep them on task, working, and moving forward.

Also, it was difficult for me because of the fact that five different experiments were being conducted and several of the groups needed me to help them through every step. One student would call me over with a question, then another group would start goofing around because they did not know what to do, and the classroom environment became unruly. Once again, I do not think this would occur with a regular 9th grade biology course, which is why next year I am planning on doing PS with my regular ed 9th grade biology students.

Another issue I dealt with was getting the pre-tests and post-tests to open. I contacted Jennifer when this happened and she got the dead links to work for most of the students. I also had internet issues at my school that eventually were resolved by the Tech Department.

Despite these challenges, I still feel that PS is an incredible program and it definitely was well worth the effort involved. I look forward to conducting PS again next year when I return to teaching general ed 9th grade biology students. Thank you for this opportunity! ☺

4. Teacher feedback on pollen field-testing (spring 2009).

Valdine McLean. Pershing County High School (Lovelock, NV). Rural School.

Alpha Testing
Teacher Feedback Form

1. *What key understandings and skills did the students demonstrate?*

Knowing where pollen came from, the difference between wind and insect delivered pollen, Size and variation of pollen, pollen tube growth, understanding how to use an internet resource to inform them of the type of wind born pollen in air that would be likely allergens, how to track it and associate it with weather patterns.

2. *How were these understandings and skills demonstrated / assessed?*

By techniques used in the laboratory – microscope, collection of pollen, staining, and id through reference slides of local known specimens, and/or internet – simply could they use these tools effectively to achieve the understandings expected of them.

3. *What key things were students expected to know or be able to do prior to the inquiry?*

Being accustomed to using the microscope, using the internet for research, and using Microsoft Excel to record data and generate graphs.

4. *What understandings and skills did the students have the most success learning?*

Measuring pollen grains, counting pollen tubes in growth solutions

5. *What understandings and skills did the students struggle the most with?*

Identification, trying to match up what they collected with what was available for references whether it was there own reference slides or internet data bases

6. *Were there aspects of the hands-on investigation that particularly helped in developing your students' understanding?*

Key aspects were the guided activities – all of them 1, 2,and 3 that directed them through both content and techniques, enabling them to develop the necessary tools to prepare them for their own inquiry.

7. *Were there aspects of the online mentoring that particularly helped in developing your students' understanding?*

Yes, the questioning by the mentors, to help guide the students is powerful. Specifically in a small school setting, where the students may have the teacher for up to 3 years for all there science instruction, as is in my case, we almost become reverted to a "parent" role. It nice to have outside "authority" guide students, it verifies that their teachers are competent as well.

8. *Please comment on the overall design of having guided inquiry activities first to develop the "tools in the toolkit" and context, with open inquiry in the last week. How well did this work? Do you have suggestions for improving this aspect?*

I think this aspect worked tremendously well – a much greater improvement then previously piloted/participated modules. More groups were able to come up with their own authentic research question than in the past, this time there was far less prodding. One group was so gun ho on the open inquiry, that I had to rein them back in to only conducting an experiment with one variable.

9. What 3-5 things would you like to see improved or changed for the next field test?

1. It was in the master matrix, but somehow it got lost, with me maybe???? The emphasis on what is going on locally needs a little more attention. With the Pollen traps activity (activity set 3) it was addressed but more as an after effect. We need to do a little more with that to make it flow just a little better. There is much information to be exploited, and with a little more work I think it will be fine next go around.
2. 3……… I don't know – we had intent to do more – ie: with morphs etc, but I found that I couldn't contribute more time. This ran roughly 3 weeks (although there were major disruptions such as a late start day and 2 days of student testing)….perhaps with the 3 interrupted days we could of done more with morphs size and scale by building models and developing another guided directed activity ????

10. Please comment on how you think the inquiry development process has gone up to this point. Any suggestions to make it better?

I think the process was wonderful …. We all seemed to be on the same wavelength, I like the weekly calls, sometimes its hectic to carve a little more piece of the pie to fit them in, but the conversation always seems to generate ideas and solve problems as we go.

11. Any other comments?

It was wonderful to work with all of you. I look forward to see where this module progresses.

B. Professional Development Activities for Scientists

1. Scientist engagement in PlantingScience activities in 2008-2009, with numbers impacted

Engagement: type, number, and intensity of personal involvement	Individuals Involved	Description of Involvement and Impact
Society partners N = 11 Combined membership of over 250,000 scientists	Botanical Society of America (BSA) American Society of Plant Biologists (ASPB) American Society of Agronomy American Society of Pant 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 4-H	Executive committees of these societies and organizations support the mission of the PlantingScience project. Individual societies will encourage members to volunteer as mentor and contribute to curriculum development and testing according to timeframes negotiated with each. This level of communication among the plant and biology organizations has rarely been seen before.
Online scientist mentors N = 241 registered mentors N = 104 mentored in fall N = 120 mentored in spring	Primarily belonging to above societies, particularly BSA, ASPB, ASPT, Agronomy. Also from organizations that are not formal partners (e.g. Geological Society) and individuals unassociated with any of these.	The total includes all individuals who have registered to serve as online mentors. Not all mentor during a given session. An average of 112 mentored this year; working with 2 teams per session.
Master Plant Science Team members N = 25	**ASPB:** Brunilis Burgos, U of Georgia; Eliana Gonzales-Vigil, Michigan State U; Lisa Kanizay, U of Georgia; Josh Rosnow, Washington State U; Ashley Spence, U of Illinois. **BSA:** Michelle Brown, UC, Riverside; Jennifer Gray, Iowa State University; Rucha Karve, Clemson U; Alona Banai, Northwestern U; Katie Becklin, U of Missouri; Marian Chau, U of Hawai'i at Manoa; Nick DeBoer, U of Hawai'i at Hilo; Frank Farruggia, Arizona State U; Kelly Gillespie, U of Illinois; Kandres Halbrook, U of Arizona; Dr. Diana Jolles, Portland State U; Rachna Kumar, U of Washington; Courtney Leisner, Washington State U; Dr. Jason Londo, Environmental Protection Agency; Julia Nowak, U of British Columbia; Amber Robertson, U of Wisconsin, Madison; Dr. Aurea Siemens, U of Alberta; Roxi Steele, U of Texas at Austin; Genevieve Walden, San Francisco State U.	The ASPB sponsored 5 graduate student members to the 2008-2009 team. The BSA sponsored 17 graduate students and 3 post-doctoral researchers. Members of the Master Plant Science Team commit to serving for both sessions of an academic year, to mentoring 3-6 teams per session, and to contributing to online discussion forums, and providing feedback.
Scientists engaged in curriculum development • Writing N = 5 • Field-testing N = 6	• **Scientists writing with teachers:** Dr. Paul Williams, Dr. Larry Griffing, Dr. B. Brown. • **In pre-writing stage:** Dr. Marsh Sundberg; Renee Smith-Lopez. • **Mentors field-testing Brassica Genetics:** B. Burgos, M. Brown, A. Roberston. **Arabidopsis:** Dr. J. Londo, G. Walden. **Pollen:** N. DeBoer.	Scientists and teachers co-writing use guidelines and *Understanding by Design* templates. Field-testing mentors shadow experiments, mentor, participate in conference calls with teachers, review materials, provide feedback.
Scientists engaged in workshops • Society mtgs N >50 • NABT, NSTA N = 2 • Summer Workshop N = 2 2008; 6 in 2009	• **Society Meeting** workshops and presentations detailed under Outreach. • **Mentor Jan Barber** co-presented workshop at **Oct. 2008 National Association of Biology Teachers** • **Mentor Margaret Conover** co-presented workshop at **Mar. 2009 NSTA.** • **Scientist presenters 2008 workshop:** Dr. Marsh Sundberg, Dr. Beverly Brown. • **Scientists 2009 workshop:** Dr. Paul Williams, Amber Robertson. Larry Griffing, Bev Brown, Teresa Woods, Sandy Honda	Scientists engage with fellow members of their own societies or other scientific societies to promote education and outreach activities, including the project. By bringing scientists to science education meetings, their understanding of secondary school contexts are greatly enhanced. Scientists leading Teacher Institutes, who are recognized as leaders of botanical education in their societies, strength connections with education.

2. Mentor feedback on A. genetics field-testing and B. pollen field-testing

A. Brunilis Burgos, Plant Genetics Graduate Student, University of Georgia.
Member of the Master Plant Science Team in 2008-2009, sponsored by the American Society of Plant Biologists.

Brunie's engagement in fall field-test of Brassica strand of Genetics Module with teacher Kathy Vanderloop and scientist Dr. Paul Williams included: shadowing student experiments by following same protocol and schedule as Kathy's classroom; mentoring 3 student teams; taking part in weekly conference calls; completing feedback form.

Online exchanges between Brunie and the MiracleGrowerz (Team 2) were particularly productive:
http://www.plantingscience.org/index.php?module=pagesetter&func=viewpub&tid=2&pid=1699

Completed feedback form:

PlantingScience Field-testing Mentor Feedback Form

Genetics, Fall 2008

Thank you for mentoring student teams during the fall field test of the Rapid Cycling Brassica strand of the Genetics Unit in development for PlantingScience. Your feedback will help us revise the RCB strand and prepare the Arabidopsis strand for the next round of field-testing. Below are a few guiding questions to focus the feedback, but please provide any additional comments or recommendations you might have.

What key understanding about genetics did you feel the students demonstrated in their conversations or documents?
Overall, I feel that they had a good understanding about variation and were able to make a connection between genotype/phenotype. They were able to visualize Mendelian genetics and at the same time understand that the environment has an effect on the way genes are expressed.

What did you expect students would understand or discuss with you that they did not?
I expected them to know what a mutation was. Some of them thought that particular phenotypes they were observing were due to spontaneous mutations in a specific part of the plant (like the pod coat) rather than at the DNA level.

Were there specific skills you felt the students gained easily or struggled with?
I think they learned how to organize their data quickly but I feel like they were not sure (struggled) how to analyze it (and understand what it meant.)

Were there aspects of your online interactions with students that you felt were particularly helpful in aiding the students' understand or skill development?
It depends on the group. Some students asked lots of questions and I felt this helped them understand their experiment better.

What 3-5 things would you like to see improved or changed for the next field test?
I think overall the field test was well organized. Perhaps one thing that can improve the students understanding of the experiment would be to choose fewer traits to study/record data. I also believe that selecting mentors that have prior experience with the model organism can improve the field test because they would already have a general idea of the timing of development, what are the "standard" traits (like cotyledon size), the environmental conditions (like ideal temperature), etc.

What do you think future mentors for the genetics investigations need to know about: (1) the genetics content, (2) the logistics of the investigation, (3) the student and teachers participating?
I am not sure if I understand this question. I think the most important thing the mentors need know about is the logistic of the investigation. If they don't understand what it is that the Field Test is trying to accomplish and what it is expected (their role) from them, it would be hard to establish a productive interaction with the students. I feel that it is important to keep one Mendelian trait as part of the experiment so that the students are able to visualize it and know what to expect. I think that working with variable traits only may be a little frustrating or even confusing for some kids. Having both Medelian and variable traits in the experimental design resembles what it in the "real world" more accurately because we all know that both of these contribute to phenotype, fitness, etc. That is an important concept that the kids should get from the field test.

B. Nick DeBoer, Biology Graduate Student, University of Hawaii-Hilo.
Member of the Master Plant Science Team 2007-2008 and 2008-2009, sponsored by the Botanical Society of America. Nick is also a Prism Fellow (GK12 program).

Nick's engagement in spring field-test of Pollen Module with teacher Valdine McLean and scientist Dr. Beverly Brown included: shadowing student experiments by following same protocol and schedule as Val's classroom; mentoring 3 student teams; taking part in weekly conference calls; completing feedback form; contributing to and reviewing drafts.

Online exchanges between Nick and Flower Power were particularly productive:
http://www.plantingscience.org/index.php?module=pagesetter&func=viewpub&tid=2&pid=2050

Completed Feedback Form:

Alpha Testing
Scientist Mentor Feedback Form

1. *Which of the Big Ideas identified in this inquiry (see below) were addressed best? Any that weren't addressed or that lost relevance during the inquiry development? Any that need to be added?*
   Big Ideas:
   1. *Pollen is integral to the life cycle of most plants (angiosperms and gymnosperms).*
   2. *Pollen from outcrossing plants is moved from plant to plant by wind, animals, water.*
   3. *The study of pollen (palynology) can reveal the interconnectedness of:*

1. *Biotic and abiotic factors in our environment*
2. *Local, regional and global geography*
3. *Diversity and distribution of plants*

I think the biggest idea addressed in this module was the interconnectedness of biotic and abiotic factors in our environment. It was something that all the groups examined by either optimizing pollen tube growth or examine the roll of wind on pollen abundance. The background information, like pollen is integral to the life cycle of most plants and pollen from outcrossing plants is moved by animals and water were hard to gauge from a mentor stand-point.

2. *What key understandings did you feel the students demonstrated in their online conversations or documents?*

Students showed their understanding of pollen moving by wind as well as biotic and abiotic interconnectedness and local and regional differences of geography. Some students demonstrated an understanding of diversity and distribution of plants. One group had a misconception about insect pollination. I'm not sure how they got there and it was only apparent in their powerpoint and never came up during discussion.

3. *What lab and activity protocols did you think were described best?*

Pauls puzzle was very well described. I think most of the things on the plantIT site were beneficial to the curriculum. The students seemed able to stain pollen fairly well too, without any apparent major hang ups.

4. *What adjustments / changes still need to be made for labs and activities to be understandable to a teacher having no prior experience?*

If there is ample background material on the process with many pictures to illustrate clearly what they are looking for in pollen staining and pollen tube growth, then these activities should be able to be accomplished by most high school teachers.

5. *Are safety issues addressed adequately in lab / activity protocols? If not, what needs to be added?*

I have no major safety issues with the current protocols. My only concern would be if a teacher tried to use a phenol stain with students.

6. *Are there other resources (online, podcasts, photos, etc.) that you can recommend?*

I find: http://www.life.uiuc.edu/help/digitalflowers/ to be a valuable resource, but understand it is beyond high school students and likely some teachers. It may be useful in the examination of flowers and cones, comparing different dispersal methods. A google image search for "pollen tube growth" shows some nice images of pollen tube growth.

7. *What prompts or general approaches worked well to create positive online interactions?*

See the big chart.
[Here Nick annotated the Matrix of Goals, Essential Questions, Objectives, Evidence of Understanding, Learning Activities, Materials, and Mentor Prompts]

8. *What were frustrating aspects of the online interactions?*

    Lack of response and a general disinterest. The experience I had with the motivated group was great, and I feel they learned a lot.

9. *What changes would help enhance the online experience between scientist mentors and students?*

If more mentors were aware of the ability to upload photos and other files themselves. If a mentor was really willing and had a high level of expertise, a video/instant messaging chat done by the mentor/scientist might be a way to provide solid feedback in a quick manner for teachers that may not be comfortable with the material.

Evaluation Report

PlantingScience

Year 2

May 28, 2009

Carol L. Stuessy, Internal Evaluator
David H. Dickson, External Evaluator

and the

Graduate Student Evaluation Team
Cheryl Ann Peterson
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Introductory Comments

This document represents a collaborative effort between external and internal evaluators with detailed input from graduate student researchers/mentors who were engaged to work with management team members and teachers during the first year's offering of the NSF-sponsored PlantingScience workshop. While high school teachers were the focus of planned workshop activities, the inclusion of doctoral-level graduate students in science education as researchers, mentors, and co-evaluators has been an additional, albeit unpredicted, broader impact of the project. The various roles these individuals have played in the implementation of the PlantingScience project have resulted in their development of new conceptions about what it means to be actors in providing professional development within a complex setting, such as that provided by PlantingScience. Graduate students have had experiences in the completion of tasks associated with planning, implementing, reviewing, and revising parts of a complex project that have involved both in-site and off-site consultants, trainers, and project management team members that include scientists, science educators, and professional training teams.

The structure of this document represents the contributions of graduate students to the evaluation component of the first year of PlantingScience. While Tori Hollas, Cheryl Ann Peterson, Laura Ruebush, and Sara Spikes provided continuity from summer workshop through teacher-participants' school year implementations, we were also fortunate to have Toni Ivey, Ra'sheedah Richardson, and Caroline Vasquez join the summer graduate team to engage in daily workshop activities and formative evaluations, as well as perform duties associated with teacher transportation back and forth to the hotel and periodic visits to local eateries and variety stores. As well, these additional graduate students contributed to data collection during the summer workshop.

Internal and external evaluators directed the activities of the three permanent graduate students on the research and evaluation team: Cheryl Ann Peterson, Laura Ruebush, and Sara Spikes. These graduate students managed and manipulated data, traveled to observe classrooms, conducted preliminary analyses of data, and wrote many sections of this report in first-draft form. As co-researchers and co-evaluators, their names are included as co-authors of this document with the internal and external evaluators.

As co-directors of the evaluation component of the PlantingScience project, we acknowledge the extraordinary contributions of the graduate student evaluation team members in collecting, organizing, and analyzing data for this report.

Carol L. Stuessy, Internal Evaluator
David H. Dickson, External Evaluator

The research reported in this evaluation document was supported in part by the National Science Foundation and the Department of Teaching, Learning, and Culture at Texas A&M University. The findings and opinions expressed in this document are those of the authors and do not necessarily reflect the view of the funding agencies or Texas A&M University.

Part I Interview Summaries

Introduction

Figures 1-7 summarize results of three sets of data that were collected during the summer 2008 workshop. Figure 1 summarizes results of pre- and post-technology interviews and a technology survey administered to teachers regarding their use of technology. Figures 2-5 summarize results of interviews regarding teachers' perceptions of their support, barriers and intentions to implement PlantingScience units of instruction. Figures 6 and 7 summarize data collected from an implementation form that requests information about teachers' intentions to participate in school year activities and implement PlantingScience units.

Technology Use Interviews and Survey

Figure 1 summarizes the pre and post-technology interview questions and a technology survey regarding the use of technology. Thirteen teachers interviewed each other using structured questions regarding their use of technology in their classroom. The survey was given to the teachers the evening before the start of the workshop. The pre-technology interview was given the first day of the workshop and the post-interview on second to last day. Two teachers left several days early. These teachers interviewed each other shortly before leaving.

According to most of the teachers, their students have used basic technology to create PowerPoints (12), online library resources (12), and word processing programs to write documents (12). Eight of the teachers' students also used programs such as Excel to create spreadsheets and charts, and computer simulations. Six teachers exposed students to the creation of graphics in their classroom. Teachers have also had students use technologies such as email (5), computer based tests (5), online course material support (4), software used to communicate about team projects and activities online (4), music and video downloading software (4), computer games (4), video/audio editing software (3), webpage creation software (2), databases that can be manipulated (2), scripting programs (1), and time lapse photography technology(1).

During the workshop, teachers were exposed to new technology in order to facilitate their inquiry into plant biology. Teachers mentioned these technologies: were time lapse photography (10), new uses of Excel to create spreadsheets and charts (7), imaging software such as Image J (7), online message boards (3), creating and editing videos (3), concept mapping software such as Inspiration (2), digital microscopes (1), and SmartBoards (1). The ten teachers who learned about time lapse photography at the workshop all plan to use it in their classroom and two other teachers would like to use it, but do not know if they will have the funds to purchase the equipment. Seven of the teachers learned about Excel though many of them used Excel in their classrooms already. These teachers (8) plan to introduce their students to new ways of using Excel to create and manage data. While Excel might not have been new, the teachers were

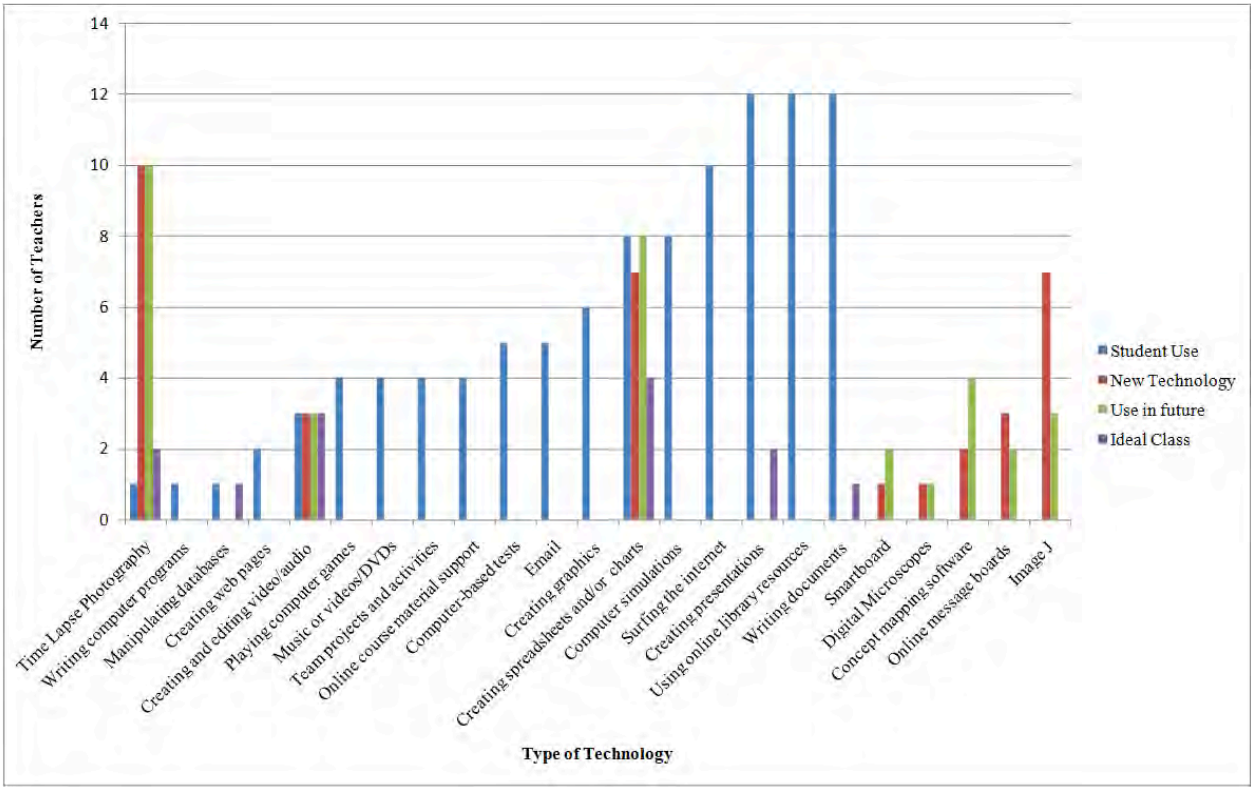

Figure 1. Categories of technology distinguished by (a) the use of technology by students in teachers' classrooms; (b) technologies that teachers were introduced to during the workshop; (c) , new types of technology that the teachers plan to use with their students; and (d) technology they would ideally like their students to use.

exposed to new ways of using it. Four teachers do not currently plan on using Excel but would like to in an ideal classroom. While Image J was new to seven teachers, only three of the teachers plan on using it in their classroom. During the workshop three teachers learned about using online communication such as message boards to communicate and two teachers plan on using it in the future. However, online communication with scientists is part of the required implementation. All thirteen of the teachers used online communication with their students though only two discussed it as a possibility. Three teachers were introduced to the creation and editing of videos during the workshop while three others already use it with their students. Three of these teachers plan on using video cameras in their classroom and three others would like to use them in an ideal class setting. Two teachers were introduced for the first time to concept mapping software and four teachers plan on using it in the future. The teacher who was introduced to digital microscopes for the first time plans on using them in his classroom.

When discussing the type of technology that their students use, teachers did not focus on forms of it that promote collaboration between students and also between students and other people. Only four of the thirteen teachers have used programs such as SharePoint that are designed to promote communication between members of team projects and activities. Only two of the thirteen teachers discussed a plan to use online message boards to promote communication between students and scientists. Teachers' students do not use collaborative technology such as Wikis, blogs, instant messaging, message boards, Face Book , and Web 2.0 programs such as Second Life in the classroom.

Support, Barriers, and Ease of Implementation Interviews

Tables 2-5 summarize teachers' responses to the Barriers to Implementation interview questions. The thirteen teachers interviewed each other using structured questions regarding possible types of support, barriers to implementation, ways of overcoming barriers to implementation, and how easy they feel it would be to implement in their classroom. Eleven of the thirteen teachers interviewed each other on the next to last day of the workshop using structured questions. The other teachers left the program several days early due to other obligations. They interviewed each shortly before they left.

Support

Figure 2 summarizes categories of teachers' responses that emerged from a content analysis of their responses to an interview question about support for technology. All of the teachers participating in PlantingScience believed that their administration was supportive. Six of the thirteen teachers felt that they did not have support from the other teachers. Reasons include apathy of other teachers, teachers who do not adapt their teaching, and actively discouraging the innovative teacher's work through theft of materials and ideas. However, teachers without support of other teachers all had other forms of support such as members of the community, university, and workshop support.

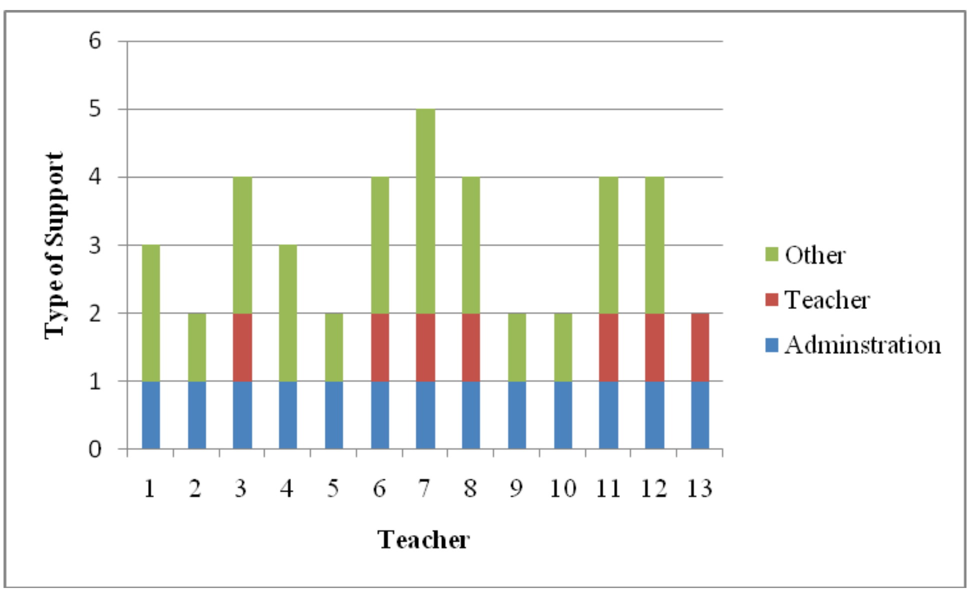

Figure 2. Available resources for each teacher.

Teachers' perceptions about other sources of support included all other types of support except teachers and administration. (See Figure 3.) Almost half of the teachers felt they had support from their local universities (6 responses) and members of the local community (6 responses). Four of the teachers had support from within their school such as technology support and science teams who set up labs. Three teachers felt that the parents would be supportive and one teacher received support from various workshops that she attends.

The main barriers to implementation (see Figure 4) that teachers anticipated were having the necessary technology available for their students (5), funding to purchase needed materials (5), and time to implement (4). Two teachers felt that it might be difficult to collect all the paperwork needed to research the implementation. Two teachers also felt that the students might not like doing the implementation unit and resist working on it. One teacher cited a personal reason for not implementing. One teacher anticipated problems with other teachers who resist the idea of innovative teaching and steal resources.

Overcoming Barriers

After being asked what barriers they could anticipate, teachers were asked about how they could overcome these barriers. (See categories of responses in Figure 5.) There is not a one to one ratio between the barriers and ideas on overcoming these barriers because teachers did not have ideas on how to overcome these barriers or they did not think something would be a barrier but they talked about overcoming it anyway. Almost half of the teachers (6) discussed how to overcome barriers to resources whereas only five teachers discussed resources as a barriers. These teachers believed that if they can not get the materials and technology they need from their schools that they could sucessfully write grants or receive help from local businesses. Five teachers felt they can overcome barriers such as paperwork and time constraints by proper preparation and time management. Five teachers also felt that if their students were to have issues with implementation that once they got started with the implementation that the students would "buy into it" and be interested. Only two teachers actually felt that students would be a barrier. Three teachers felt that their various barriers could be overcome by implementing on a smaller scale first such as afterschool or with only one class. Three teachers felt that with proper communication barriers they could have a sucessful implementation.

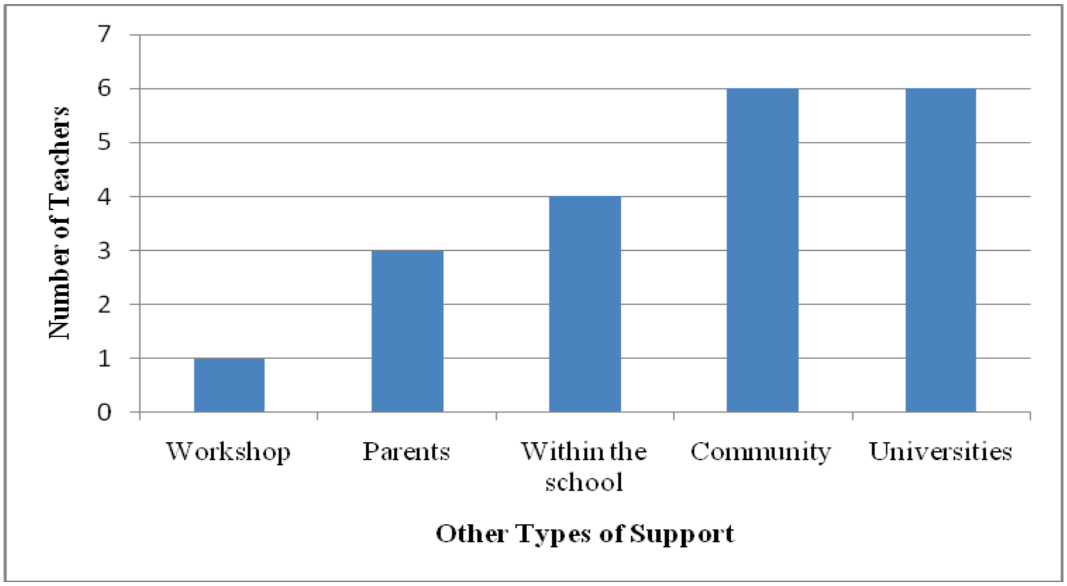

Figure 3. Other types of supports.

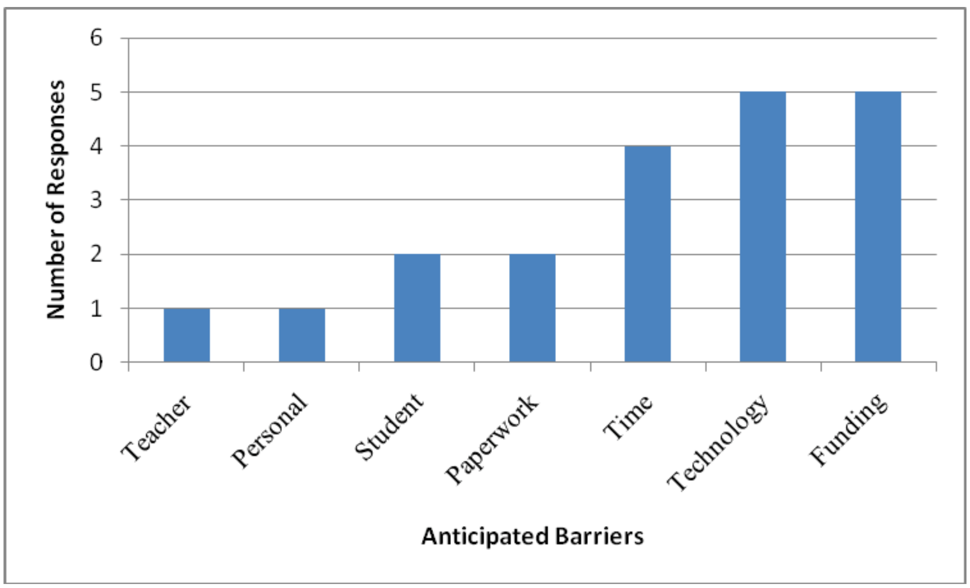

Figure 4. Anticipated barriers to implementation.

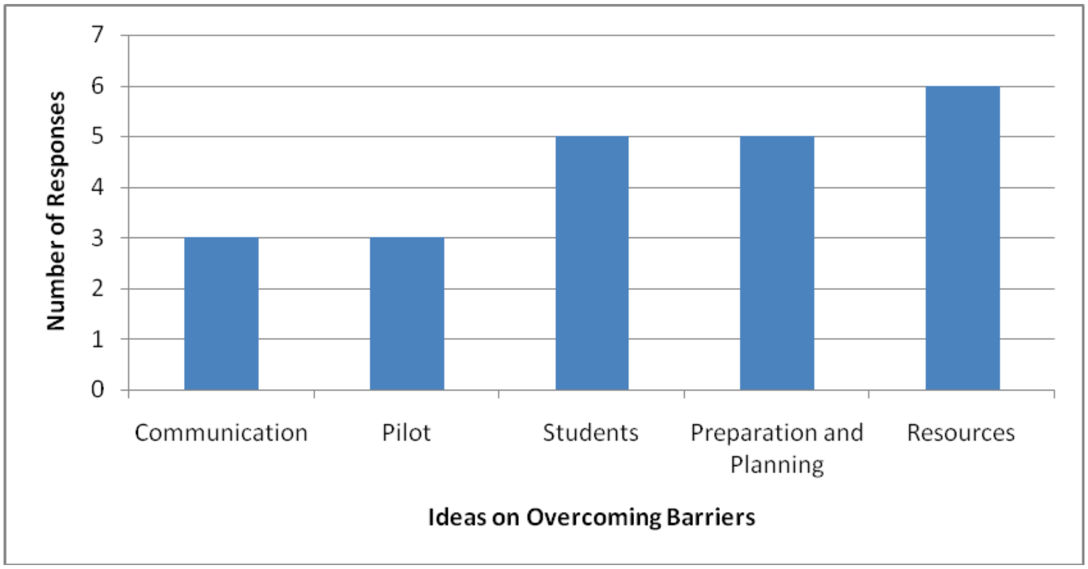

Figure 5. Teachers' ideas on overcoming barriers to implementation.

Ease of Implementation

While teachers have discussed numerous barriers to implementation, they have also provided ideas on overcoming these barriers. All the teachers have done something innovative in the past with their students and plan to continue innovative teaching practices. All of the teachers believed that they have the support of their adminstration and another form of support. Almost all of the teachers (12) believed that their implementation would be easy and only one teacher was unsure about her ease of implementation. All PlantingScience teachers implemented this past year.

Implementation Plans

Teachers were asked to fill out a planned implementation form on the last day of the workshop. The teachers were asked what role they planned on filling for PlantingScience (implementer, portfolio teacher, and/or teacher researcher), which inquiry unit(s) they were going to implement, and implementation details. Two teachers left early and did not fill out their implementation plans. The following data analysis represents the remaining eleven teachers.

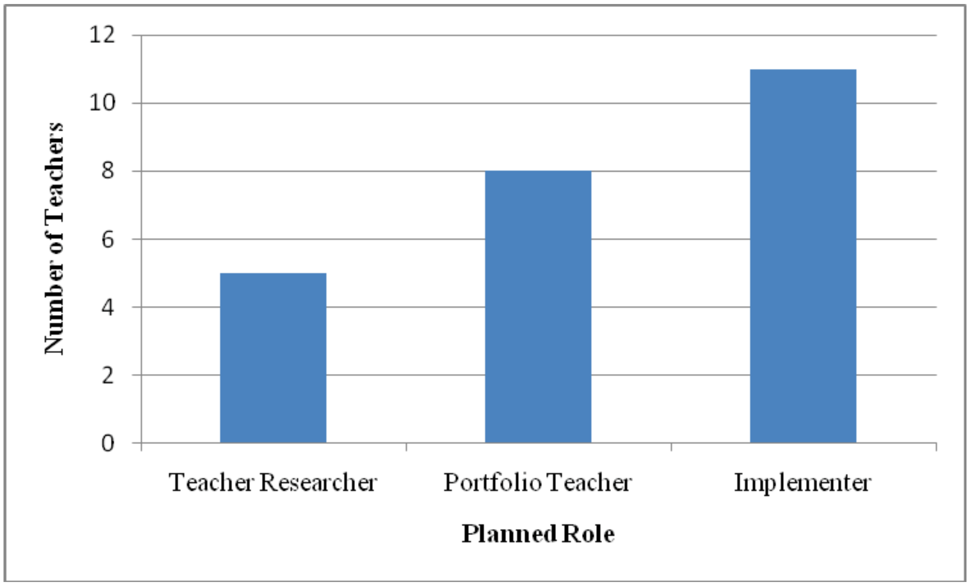

Figure 6. Planned role of teacher in the PlantingScience program.

All teachers planned on implementing. Eight of the eleven planned on being portfolio teachers. Five teachers planned on being teacher researchers.

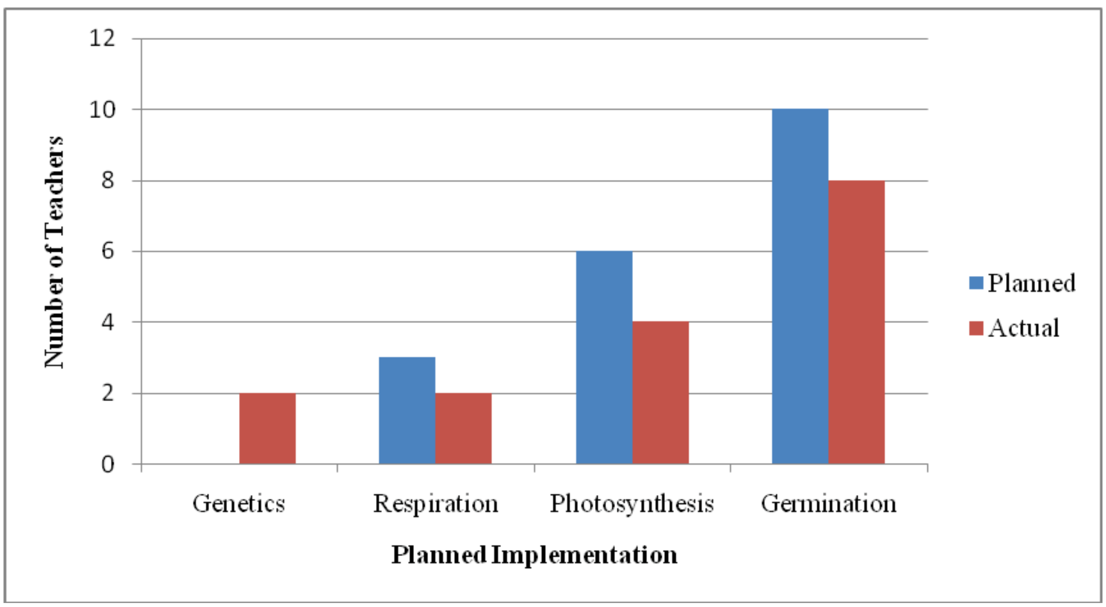

Figure 7. Planned implementation inquiry units.

All teachers planned to implement at least one of the PlantingScience inquiry units. Several teachers planned on multiple implementations. The most popular unit was germination where ten teachers planned to implement it and eight teachers actually did. Photosynthesis was the second most popular with six teachers planning to implement it and four teachers actually implementing the unit. Respiration had the least amount of teachers planning to implement it (3) and had only two teachers implement it. Two of the teachers decided to further their role with PlantingScience and test an inquiry unit that was still in development. This was the genetics unit that teachers will work with this upcoming summer. The two teachers who did not create implementation plans (whose data are not included in the above analyses) both implemented all three of the of the inquiry units. One of the two teachers also tested the genetics unit.

Outcomes

Information from the PlantingScience website indicate that all teachers implemented at least one science unit during the 2008-2009 school year. See the principal investigator's report for more information on those implementations.

Part II Classroom Case Studies of PlantingScience Teachers

Methods

About the Observation Instrument

The Mathematics and Science Classroom Observation Profile System (M-SCOPS) is an observation system created to fill a void in traditional classroom observation research by incorporating current understandings of cognition and instruction into pictorial representations of K-12 science classrooms. (See Stuessy et al., 2005.) M-SCOPS profiles translate observation scripts into visually complex profiles that communicate interactivity among teachers and students with instructional materials and technologies. Interactivity highlights students' and teachers' use of multiple representations, including symbols, numbers, graphs, diagrams, models, and other common tools of the mathematician's and scientist's trades, occurring within the context of mathematics and science learning and teaching environments.

M-SCOPS has been used in both teaching and research contexts to describe theoretically optimal classroom learning environments, compare actual science teaching and learning environments, correlate instructional patterns with academic performance, and enhance classroom teaching practices of novice and experienced science teachers. The M-SCOPS also has been used effectively in interpreting and analyzing videotapes of intact classrooms, where the focus centers on the interactivity between teachers and their students.

The M-SCOPS was designed to be a tool to describe the complex activities occurring during mathematics and science lessons. The tool is not used to characterize "right" or "wrong" teaching; nor do percentages of activities spent in direct instruction or student-directed learning indicate "good" or "bad" lessons. Scripts, codes, profiles, and frequency tables assist the mentor or classroom observer in documenting "what went on that day," to reflect on frequencies of occurrences during multiple observations of particular teachers, and to reveal patterns and their changes that may occur over time. In instances where teachers are exposed to mentoring and/or professional development experiences that occur over a long period of time, the M-SCOPS has been shown to be effective in documenting the effects of professional intervention on teachers' abilities to effectively orchestrate the classroom learning environment.

Observation Methodology

The M-SCOPS was used in these case studies as the major data source for answering the question, "What goes on in Planting Science classrooms after a high-quality summer professional development workshop?"

GA observers made appointments to visit PlantingScience teachers' classrooms for three days. The classroom case studies were constructed from interview data collected during the summer workshop (see Part I) regarding both of the teachers observed. GA observers then made appointments with the two volunteer teachers to observe a sequence of three of intact science classroom lessons and conduct follow-up interviews to clarify their observations. Observers then used the MSCOPS electronic profiling system to develop classroom profiles and generate simple descriptive statistics about each of the classes observed. Important features of the classroom learning environment were derived through the use of all of the M-SCOPS tools, which include scripts, codes, visual profiles and descriptive statistics. Scripting sheets were used to document content and behaviors of teacher and students from the observer's perspective. Observers used tables 1 and 2 (see below) to match observations with codes for instructional strategies and complexity levels, respectively, in order to code their scripts. Coding was verified by a third researcher (the internal evaluator) well versed in the use of the coding scheme to assure good inter-rater reliability.

These case studies include visual profiles to represent classroom interactions occurring during the lesson and tables of descriptive statistics regarding levels of student-centeredness (see Table 1, *Instructional Scaffolding*), and levels of complexity in students' reception and actions on symbolic (verbal and/or mathematical) information, three-dimensional objects, and pictorial representations (see Table 2, *Representational Scaffolding*).

Scripts, which may be entered manually on scripting sheets or electronically on the M-SCOPS program, were created for each class that was observed. Scripting sheets provide three columns in which to enter verbal information for each segment of instruction. A segment of instruction, which is defined with a beginning and an ending time within the lesson, is recorded on the script. When the activity of the students changed (say, from listening to the teacher to working in the laboratory), the script changes to the next segment. In the MSCOPS scripts, the entire lesson is described in terms of what the teacher and students are doing and what types of information students and receiving and acting on. Unlike many other observation instruments that just take a "5-minute snapshot" every 10 minutes of a lesson, for instance, the MSCOPS scripts events of the classroom as a series of segments that "flow" from one segment into the next. For each segment, the three columns are labeled as, "What the Teacher Is Doing," "What Information (Content) the Students are Receiving," and "What the Students Are Doing." In field-testing the instrument, we found that the first two columns, "What the Teacher Is Doing," and "What Information the Students are Receiving," can be very different. If students are engaged in a computer simulation, for instance, the students are both receiving and doing, or acting on, the computer simulation. The teacher may be monitoring the class, working with individual groups of students, or some combination of both during that segment.

Coding is done by the observer with the use of tables 1 and 2. The script is read, and two different types of codes are applied to each segment of instruction. Tables summarizing the codes, which were validated by a team of educational researchers, provide the coder with information about the level of instructional strategy and the complexity level of the information being received and being acted on by the students. For each segment, the level of the instructional strategy employed by the teacher (see Table 1) ranges from a score of 5-1 to 0-6, depending on the levels of Reception and

Direction (R&D) and Student Performance and Initiative (P&I). Levels of complexity (see Table 2) are coded at levels to represent the cognitive complexity of the information being received and/or acted on. Students within the lesson can receive information and act on in the form of symbols (verbal or mathematical), objects, and/or pictures. In complex representations and models of natural phenomena, such as those which occur in computer simulations, all forms may be present, and students may be receiving and acting on information simultaneously in their attempts to manipulate components of the system being represented.

Coded scripting sheets provide the data for drawing the profiles, which are read from "bottom-up." The black line in the middle of the profile separates the activities of students from those in which they are *Receiving and/or Being Directed* from those in which they are Initiating and/or Performing (i.e., *Acting On*) information. The beginning and ending times for each segment are converted into percentages, which form the height of each segment. Instructional strategy codes are colored red; with verbal information coded in yellow, pictorial information coded in green, and three-dimensional objects coded in blue. The profile allows the observer to look at the lessons "as a whole," interpreting the flow in segments from more teacher-directed strategies to those in which students have more control in their own learning, as well as the complexity of the lesson (width of each segment) and the types of representations available to the student during the lesson. (See Stuessy et al., 2005, for more information about the M-SCOPS tools.)

Descriptions follow that summarize classrooms observed, scripted, coded, and described by Graduate Assistant observers. PlantingScience teacher-participants volunteered themselves and their classrooms to be observed. The narratives that follow were written by the individuals who observed each of the classrooms. The final Commentary summarizes observations of all classrooms from all PlantingScience teachers who were observed after the first summer's workshop.

Table 1
Instructional Scaffolding Strategies

R&D[1]	P&I[2]	Description	Examples
5	1	Individual students are directed to listen as the teacher or another student talks to entire group; students are directed to read or do seat work; assimilation and/or accommodation occur passively with little or no interaction	Direct instruction models, including those where the teacher asks rhetorical, yes-no or one-word answers; lecture, silent reading, independent practice, seat work
4	2	Individual students respond orally or in writing to questions asked by the teacher, in whole group; responses are shared	Teacher-led recitation; question and answer; discussion led and directed by the teacher
3	3	Students in pairs or small groups work together under the teacher's supervision – with discussion; all groups do basically the same task	Student discussion in groups; may include task completion, verification laboratories, cooperative learning models
2	4	Groups and/or individual students work on different tasks; while all are participating, tasks may be very varied; but they are coordinated, as when one group presents and others ask questions or evaluate results; loosely supervised by teacher with teacher intervention	Individuals or groups present information while the rest of the class responds; intervals of work are often interrupted by the teacher to coordinate activities or encourage sharing
1	5	Students in pairs or small groups discuss, design, and/or formulate their own plans for working in class on a specified task; minimal supervision for longer periods of time; little coordination by the teacher	Open-ended laboratory or project work, invited by the teacher but definitely where students are less restricted
0	6	Individuals or groups carry out their own work independently; minimal supervision	Individualized laboratory or project work

[1]R&D refers to Reception and Direction. [2]P&I refers to Performance and Initiative

Table 2
Complexity Levels of Representational Scaffolding

Action	Complexity Level	Receiving	Acting
Attend	**1**	External or superficial features, attributes, directions to perform a level 1 action	Listen to, attend to, observe, watch, read, view
Replicate	**2**	Pictures, models, examples, identifications, descriptions, explanations, clarifications, calculations, duplications, measurements, reproductions, demonstrations, algorithms, level 2 directions	Recall, remember, list, tell, label, collect, examine, manipulate, name, tabulate, identify, give examples, describe, explain, clarify, calculate, document
Rearrange	**3**	Comparisons, groupings, sequences, patterns, rearrange-ments, balancing, classifications, disassembled parts of a whole; processes of putting parts of a whole together, level 3 directions	Compare, group, put in order, rearrange, identify a pattern, paraphrase, balance, classify, identify parts of a whole, assemble parts to make a whole, disassemble parts of a whole
Transform	**4**	Different representations of the same system; arrangements of complex parts into a whole system, transformations, changes, level 4 directions	Represent symbolically or pictorially, experiment, interpret, contrast, apply, modify, make choices, distinguish, differentiate, transform, change, arrange complex parts into a system
Connect	**5**	Alternative points of view, connections, relationships, justi-fications, inferences, predictions, plans, hypotheses, analogies, systems, models, solutions to complex problems, level 5 directions	Connect, associate, extend, illustrate, explain relationships in a system, use and/or connect representations to develop explanations, explain different points of view, infer, predict, plan, generate hypotheses, use analogies, analyze, generate solutions to complex problems already conceived, rank with justification
Generate	**6**	Analyses, evaluations, summaries, conclusions, abstract models and representations, problem scenarios, level 6 directions	Justify, defend, support one's own point of view, develop or test one's own hypotheses or conceptual models, define relationships in new systems, generalize, recommend, evaluate, assess, conclude, design, generate a problem, solve a problem of one's own generation

About Teacher Belief Surveys

A research component of the PlantingScience project was to collect information on teachers' beliefs about reformed practice to use in longitudinal studies investigating the role of teachers' beliefs in implementing reformed practice. While not a part of the evaluation component of the PlantingScience project, the first year's data on teachers' beliefs are included in the classroom case studies that follow on Toni and Michael. Instruments were chosen for predictor variables to measure self-report data from teachers regarding their reformed practice and attitudes towards teaching. These instruments included the following:

> *(1) The Modified Best Practice Survey* (MBPS), which measures the frequencies with which teachers report the use of traditional strategies such as lectures, a text-driven curriculum and isolated learning along with the frequencies with which they use reform strategies such as experiential learning, use of primary sources of data, and collaborative learning. The MBPS has three subscales: *Frequency* (in occurrence of the practice), *Importance* (of the practice), and *Preparedness* (to use the practice).
>
> (2) *Science Teaching Efficacy Beliefs Instrument* (STEBI), which measures in-service teachers' self efficacy using two different dimensions. The first examines teachers' beliefs about their own ability to be an effective teacher. The second dimension looks at the teachers' beliefs about whether students can learn if effective teaching takes place. This instrument has been successfully paired with CBATS in prior studies.
>
> (3) *Context Beliefs about Teaching Science Instrument* (CBAT), which measures context beliefs about the science teaching environment. When used with an instrument that measures self- efficacy (e.g., STEBI), this instrument can be used to determine factors which predict particular personal agency belief patterns, assess teachers' perceptions of the strengths and weaknesses of school science programs, and could be used in planning and monitoring professional development experiences for science teachers.

Normalized scores of the teachers involved in the two classroom case studies are reported in the introductions of both teachers to provide some insight into the beliefs of these teachers.

Classroom Case Study of Toni

An Introduction to Toni

The PlantingScience teachers were given survey instruments and a perceptions of technology interview at the beginning of the workshop with the intent of understanding how well teachers' incoming perceptions and practices predict their levels of reception of the summer workshop. The level of reception of the summer workshop was measured using transformed interview data. These instruments will also used to predict the teachers' levels of classroom implementation of the intervention.

Toni sees herself as a moderately effective teacher capable of recognizing effective teaching strategies (STEBI=0.76). She is unsure of the ability of an increase in support and training to enable her to be a more effective teacher (CBAT=0.78). She recognizes the importance of implementing reform-based curricula (MBPS-import.=0.88) and attempts to implement such curricula in her classroom (MBPS-freq.=0.81). However, she reports feeling less prepared to do so (MBPS-prep.=0.73).

Toni completed the pre-technology survey, which was designed to understand the teachers' perceptions of technology and innovative technology use in the classroom. Toni has changed all of her laboratory experiments from the traditional cookbook labs to various forms of inquiry. She tries to engage her students in research and connect them with various university or scientist through various professional development workshops she has attended. The availability of technology varies from year to year depending on school needs and accessibility. Computers are generally available for student use. Her classroom is equipped with a smart board and projector. She feels technology is beneficial for her students when she can get it to work, and frustrating when it does not. Her students sometimes show more interest in completing on-line simulations of a laboratory than completing the same type of lab hands-on. She feels that these simulations helps keep the students focused on the content rather than getting caught up in the procedures. She feels that the students learn to use technology very quickly, but are sometimes hesitant to go through the learning process. Her students are often teaching her things she does not know about technology. She uses technology to support group work usually in pairs. When presentations are required, she has students conduct small round table discussions to share their results with the class instead of one at a time. The integration of technology in her classroom enables students to be more engaged and interested with the content. She feels like national and state standards should be met, since they are the minimum level of proficiency for enabling the students to be successful outside of the education system.

Toni would like for students to engage in innovative technology experiences because she feels like they are more engaging and traditional PowerPoint presentations are uninteresting. As an innovative use of technology, she would like to integrate the use of wikis into her classroom. Time is the largest factor to enable the integration of these types of experiences in the classroom. The on-line collaboration with scientist is a unique aspect of implementing PlantingScience in the classroom. However, she feels like students do not appreciate the time that the PlantingScience scientist mentors take to interact with them in the on-line environment. Her school has a lot of technology available, but it seems that only a handful of teachers actually use technology as an innovative instructional tool.

Toni completed interviews at the end of the workshop which were designed for feedback and to find out about teachers' levels of reception of the workshop. These interviews looked at perceptions of technology use in the classroom and barriers to implementation.

At the conclusion of the workshop, Toni said that she would like to increase the use of imaging analysis software, such as Image J, in her classroom. She already uses digital cameras to collect images. She would also like to use Inspiration, software for concept mapping. Toni would like to begin introducing freshman to Excel, she feels this is necessary to help them be more successful later in high school and college. She feels students are more confident to troubleshoot and problem solve when using technology rather than traditional laboratory equipment.

Toni reports that administration determines the level of ease associated with implementing innovations in her classroom. She does have enough materials on hand to conduct the experiments she would like. The chemistry, physics, and biology teachers at her school are set up on a rotation to enable a three-pronged approach to science instruction. The technology department at her school is also a support. They set up distance learning opportunities so students who cannot be on campus can still participate in science activities.

This is Toni's second year implementing PlantingScience in the classroom. She does not foresee any problems with administration. Her administration encourages integrating these types of activities in the classroom, especially when they will also cover the state standards. She makes sure involve herself in public relations with respect to the program to ensure parents and other faculty are aware of the type of progress being made in the project. She would like PlantingScience coordinators to provide more continuity with research articles and the corresponding grading rubrics.

Toni's Implementation

Toni begins most class periods with practice state assessment questions immediately as students enter the classroom. After going over the answers to the practice questions, Toni directs students to take their labs out and checks each for the inclusion of proper safety procedures. Students then move back to the lab, put on safety equipment, and begin conducting their experiments. Each group has selected various plant tissues to use to collect respiration measurements. While working in small groups, students must negotiate roles, divide tasks, and troubleshoot procedures.

Day One was designed as a practice day for students to collect at least two trial runs of the experiment. One group came up with an interesting method for keeping track of data collection. After they shared this with Toni, she called for the attention of the entire class as the group shared their reasoning and solutions for the problem. As the students clean up and leave class, each group gives Toni a report of data and preliminary analysis. Toni encourages each group to think about what they did and what could have gone wrong.

Day Two began in the library for students since the sign was left on the classroom door from the previous period. Students sit within close proximity of their groups in the library. This enables them to negotiate who will complete the various portions of the on-line write-up. During this time, students also compare notes to make sure that a complete record is being uploaded to the PlantingScience site. Toni monitors work and provides guidance on an as needed basis. If the students have completed their sections, she encourages them to continue to do background research and checking their notes for completeness. In the last few minutes of class, the students return to the classroom to complete the practice state assessment questions.

Day Three began with students completing the practice state assessment questions. Toni then briefly goes over the agenda of all the tasks which need to be completed and the products to be turned in by the end of class. Students spent the majority of the time working in small groups in the laboratory. Toni monitored each group's progress and helped troubleshoot and think about alternatives as problems arose.

Toni has established a clear and consistent routine in her classes. Although her class has a lot of structure, she enables her students to actively engage in the material and follow their own interests. She begins most class periods with practice state assessment questions, goes over the day's agenda, and then begins her daily instruction. As far as implementing the PlantingScience curriculum, Toni has an established laboratory notebook set-up for each of her students to use (see figures 1 and 2). Toni indicates on her daily agenda board which portions of the lab notebook have been completed, which ones students are working on, and when the completed notebook is due. Toni provides the students with a format for completing each section of the laboratory notebook with the information they need for the experiment.

Toni feels that her instructional day has been successful when the students are able to come in and get to work. She feels that process and content is most important. Teacher preparation for the lab is essential to have successful implementation. The practice day completed on day one was necessary for students to be able to collect sufficient data on the third class day. She reports feeling like both the students and teacher need to have sufficient time to troubleshoot materials and work through the concepts to be sure that misconceptions between photosynthesis and respiration are not formed. She feels this is most easily accomplished by making sure you implement the appropriate level of inquiry based on time constraints in your classroom.

Energy Production and use in cells Background research	Notes	Lab materials and set-up	Experimental design and procedure	Experimental data and analysis

Figure 1. Lab notebook (5 ½-sheets of paper taped together to be used with experiment for each student)

Experimental design and procedure – Question:

Hypothesis (Prediction):

If ______________energy usage is compared to ________________ energy usage then____________________ will (use more/thesam/less energy).

Safety:
1.
2.
3.
4.

Procedure (Experimental design)
1.
2.
3.
4.
5.

Experimental data and analysis

Data Tables

Trial 1

Trial 3

Trial 2

Trial 4

Figure 2. Information to be filled in by each student for various sections of the laboratory.

Lesson 1 (TL1): Inquiry Sequence on Energy Production and Usage in Cells

Lesson Flow

This 8-segment lesson begins with 2 teacher-directed (5-1, 5-1) introductory segments (see segments 1 and 2 below). In the third segment of the lesson, objects are introduced, and students continue to work with objects until the eighth and final segment. Groups work on the same task in segment 3 (3-3) which then progresses to tasks where students are provided some freedom in determining how they will accomplish the task (segment 4, 2-4), interspersed with 3-3 segements (i.e., segments 5 and 7) and more student-directed segments (i.e., 6 and 8). There appears to be no teacher-directed closure to the lesson, as students in the final segment of the lesson are still working in groups under their own direction.

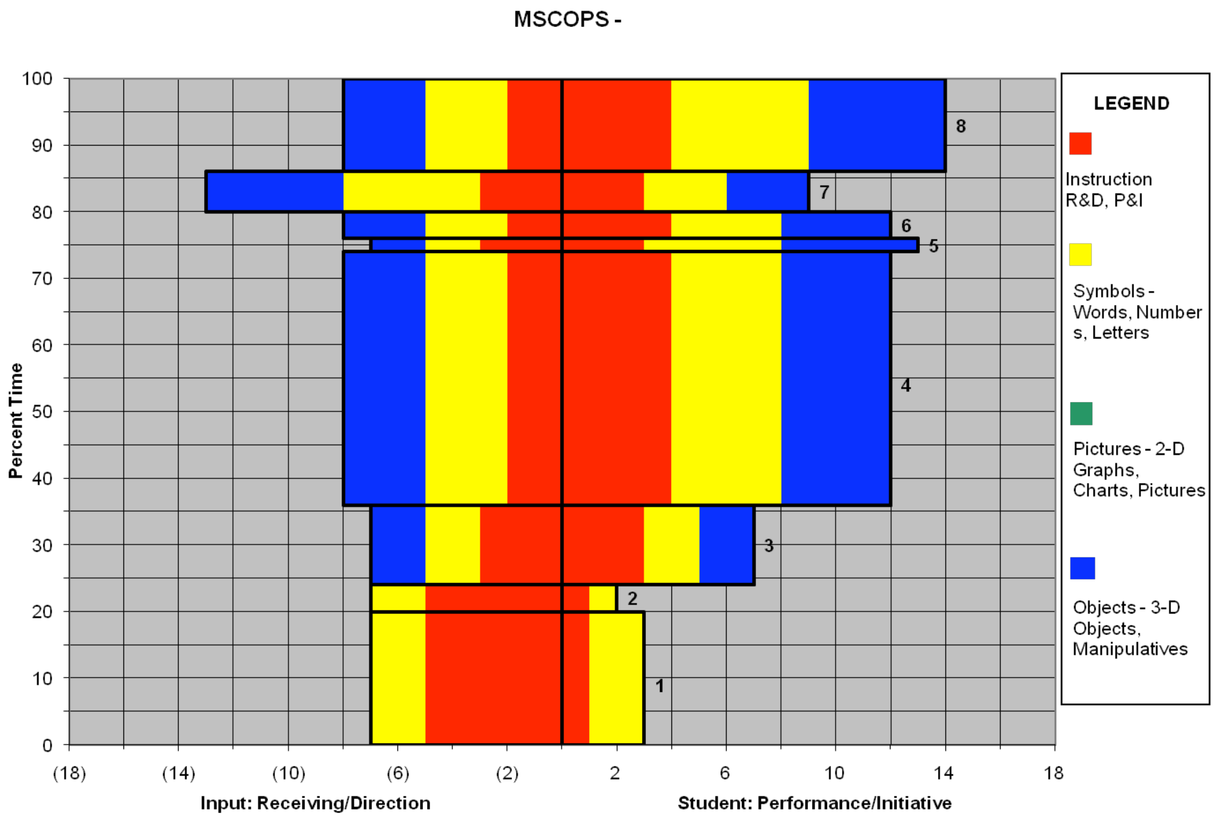

Figure 1. MSCOPS profile for Toni Day 1.

Levels of Reception and Direction (R&D) vs. Performance and Initiative (P&I)

Students were active learners (levels of P&I = or > 3) for 76.0% (= 3, 20.0%; =4, 56.0%) of the 50-minute class as they worked in small groups to complete experiment (68.0%) and listening to group present about troubleshooting procedure (8.0%). Passive learning therefore occurred about 24.0% of the time.

Students' Engagement with Verbal, Pictorial, and Symbolic Information

Class began with students completing and discussing practice state assessment questions (Symbol level 2). Toni then leads a discussion over the safety procedures for the lab and checks each student's write-up to ensure safety compliance (Symbol level 2). Students then move back to lab and put on safety gear (Symbol level 2; Object level 2). As students work through the experiment many groups troubleshoot the set-up, establish roles, clarify procedures, and collect data (Symbol level 4; Object level 4). After about 20 minutes of working in small groups, one group announces and describes a successful troubleshooting of the procedure (Symbol level 5; Object level 5) while other students listen to their suggestions (Symbol level 3; Object level 3). Students finish collecting data until the end of class (Symbol level 4; Object level 4) and report their data and preliminary analysis to Toni (Symbol level 5; Object level 5).

Table 1

Percentages of time spent by student receiving and acting on symbolic information at different levels of complexity

Levels of Symbols	Receiving % Time	Acting % Time
1	0.00	4.00
2	38.00	32.00
3	56.00	6.00
4	0.00	42.00
5	6.00	16.00
6	0.00	0.00

Table 1 summarizes students' activities as they received and acted on symbolic information during the lesson. Students acted on symbolic information at complexity levels 4 (42.0%) and 5 (16.0%) through small group laboratory activities where they were presented with level 3 (56.0%) symbolic information. Students received level 5 (6.0%) symbolic information as Toni encouraged troubleshooting and alternative solutions; however, students acted on this at level 3 (6.0%) as they compared the presented set-ups to their own. Students received and acted at a level 2 for 21.43 % of the time when they were using the PlantingScience website and learning about the leaf mode. Students received and acted at a level 2 for 32.0 % of the time when they were going over state practice questions and going over safety equipment necessary for the experiment. Students also received verbal information at level 2 while listening (acting level 1, 4.0%) to the day's agenda.

Table 2 summarizes the percentages of time that students received and acted on objects during the class. Students received and acted on object-based information equal times throughout most of the class period (76.0%). Students neither received nor acted on pictures during this class period.

Table 2

Percentages of time that objects and pictures were used during class.

	Action	% Time
Objects	Received	76
	Acted On	76
Pictures	Received	0
	Acted On	0

Summary

Students spent the majority of time during this class period working in small groups practicing their experimental technique and troubleshooting their set-ups. Students negotiated roles and divided tasks between members of the group. Toni monitored progress and answered questions regarding the procedure as the students worked.

Lesson 2 (TL2): Inquiry Sequence on Energy Production and Usage in Cells

Lesson Flow

This lesson consisted of 5 segments, beginning with a short introductory segment in which students acted on verbal information, pictures, and objects at low complexity levels. Segment 1 was followed by a 2-4 segments in which groups of students were able to make decisions about the ways in which they interacted with objects and pictures. Segment 3 (5-1) was a very short segment that prepared students for the bulk of the class activity (see segment 4 below), in which students worked at high complexity levels with both pictures and objects. This lesson closed in segment 5 with a discussion (4-2).

Levels of Reception and Direction (R&D) vs. Performance and Initiative (P&I)

Students were active learners (levels of P&I = or > 3) for 83.7% (= 4, 83.7%) of the 50-minute class as each group decided on the content and the author of each on-line section. Passive learning therefore occurred about 16.3% of the time.

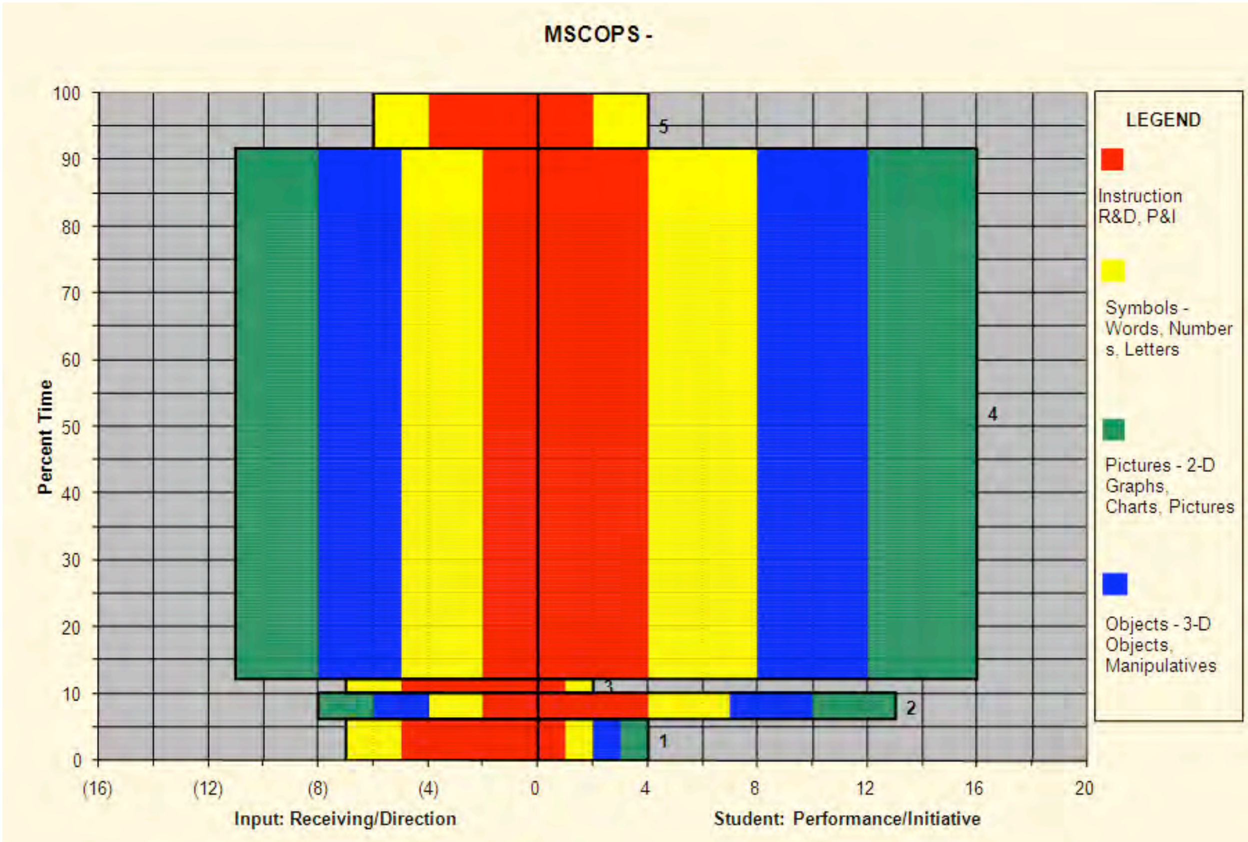

Figure 2. MSCOPS profile for Toni Day 2.

Students' Engagement with Verbal, Pictorial, and Symbolic Information

Class began with Toni going over the tasks to be completed by each group by the end of the day (Symbol level 2) as students logged onto the PlantingScience website (Symbol level 1; Object level 1; Picture level 1). Students divided tasks and wrote-up their individual parts (Symbol level 3; Object level 3; Picture level 3) as Toni helped individuals recall what they had done in lab and answer questions regarding the content of their write-up (Symbol level 2; Object level 2; Picture level 2). Toni often reminds the students about which sections must be completed to earn the various grades associated with the project (Symbol level 2) as they continue to work on the assignments (Symbol level 1). Students spend the majority of time working on individual tasks within their group including writing up their information from the days prior or continuing research (Symbol level 4; Object level 4; Picture level 4) as Toni monitors their progress and provides guidance and support throughout the process (Symbol level 3; Object level 3; Picture level 3). Class ends with the daily practice state assessment questions (Symbol level 2).

Table 3 summarizes students' actions on verbal information. Students spent most of the class acting (79.59%) on level four symbolic information through independent work within their groups writing up their experiments where they were presented with level three (79.59%) symbolic information. Students listened to instruction (acting level1, 8.16%) as they received level two for 20.41% of the time when they were discussing (acting level 3, 4.08%) the parts of the lab to be included in the write-up as a class and tasks to be completed by the end of class. Students received and acted at a level two for 8.16 % of the time when they were going over state practice questions.

Table 3
Percentages of time students spent receiving and acting on symbolic information at different c complexity levels during Lesson 2.

Levels of Symbols	Receiving % Time	Acting % Time
1	0.00	8.16
2	20.41	8.16
3	79.59	4.08
4	0.00	79.59
5	0.00	0.00
6	0.00	0.00

Table 4 summarizes percentages of time that students spent amounts of time receiving objects and pictures (83.7%) throughout the class period. Students spent slightly more time acting on both objects and pictures (89.8%).

Table 4
Percentages of time students spent receiving and acting on objectives and pictures during Toni's second class.

	Action	% Time
Objects	Received	83.67
	Acted On	89.80
Pictures	Received	83.67
	Acted On	89.80

Summary

Students spent most of this class period working individually to type up various parts of their groups' experiments. Roles were negotiated within each group so that each group member was responsible for a portion of the assignment. Students seemed to be familiar with the PlantingScience website and comfortable using technology.

Lesson 3 (TL3): Inquiry Sequence on Energy Production and Usage in Cells

Flow

This 3-segment lesson began with two short segments 4-2, 5-1) before releasing students to work in groups under their own direction for the third and last segment, which lasted for about 80 percent of the class period. There was no formal closure to this particular lesson.

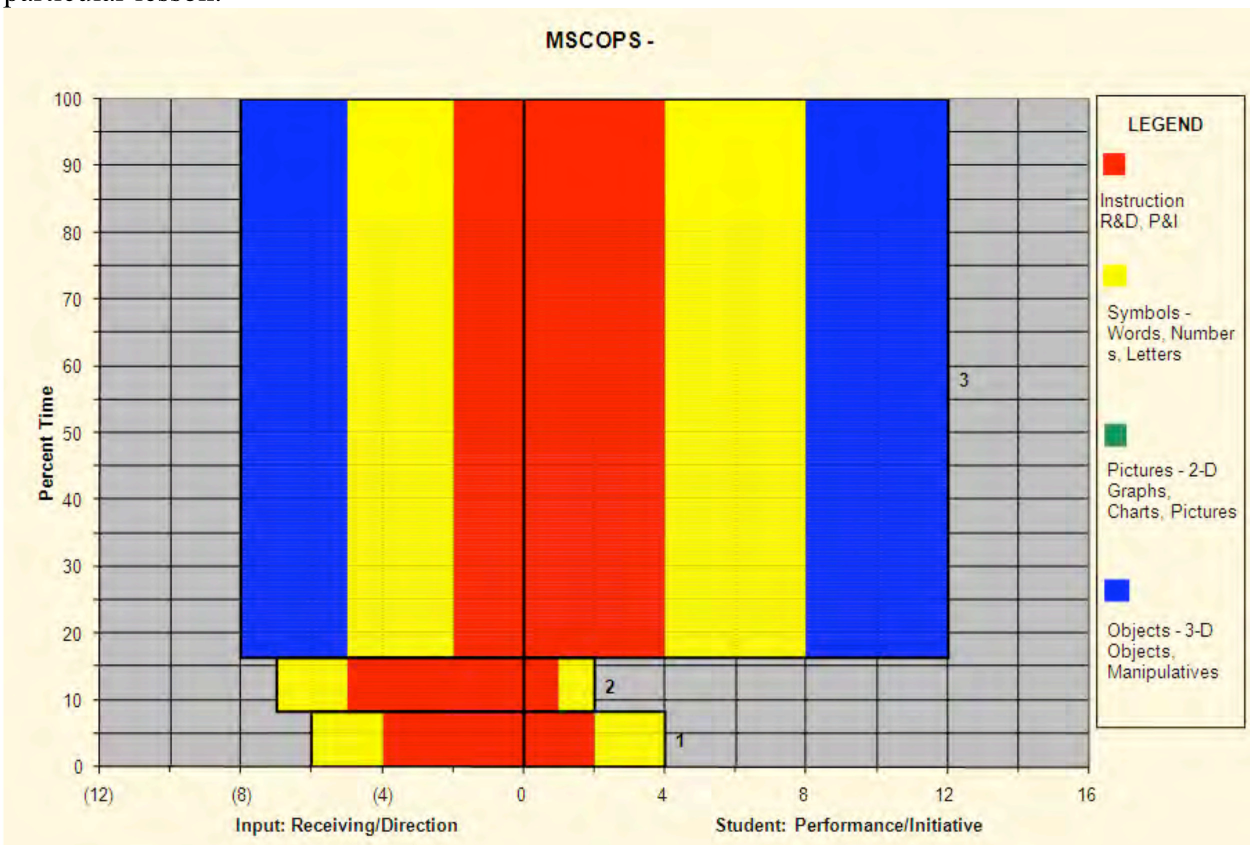

Figure 3. MSCOPS profile for Toni Day 3.

Levels of Reception and Direction (R&D) vs. Performance and Initiative (P&I)

Students were active learners (levels of P&I = or > 3) for 83.7% (= 4, 83.7%) of the 50-minute class as students worked in small groups to conduct their unique experiments. Passive learning therefore occurred about 16.3% of the time.

Students' Engagement with Verbal, Pictorial, and Symbolic Information

Students' interactions with verbal information are summarized in Table 5. Class began with practice state assessment questions (Symbol level 2). Toni then briefly went over the day's class agenda (Symbol level 2) as students listened to expectations (Symbol level 1). Students worked in their groups for the duration of the class (Symbol level 4;

Object level 4) as Toni monitored their progress and helped them think of alternative solutions as problems arose (Symbol level 3; Object level 3).

Table 5

Percentages of time students spent receiving and acting on symbolic information at various complexity levels in Toni's third lesson

Levels of Symbols	Receiving % Time	Acting % Time
1	0.00	8.16
2	16.33	8.16
3	83.67	0.00
4	0.00	83.67
5	0.00	0.00
6	0.00	0.00

Table 6 summarizes percentages of time that student spent interacting with objects and pictures. Students spent most of the class (83.67%) acting at a level four symbol through individual laboratory activities which were presented with level three (83.67%) symbolic information. While listening to an explanation of the daily agenda students received level two (8.16%) and acted on level one (8.16%) symbolic information. Students received and acted at a level two for 8.16 % of the time when they were reviewing state practice questions.

Table 6
Percentages of time spent by students receiving and acting on objects and pictures in Lesson 3.

	Action	% Time
Objects	Received	83.67
	Acted On	83.67
Pictures	Received	0
	Acted On	0

Students spent equal amounts of times receiving and acting on objects throughout most of the class period (83.7%). Students did not receive or act on pictures during this lesson (0%).

Summary

Students spent the majority of time during this class conducting their own investigations related to energy usage and production in various types of plant tissue. Toni provided guidance and asked probing questions as she monitored group progress.

Classroom Case Study of Michael

An Introduction to Michael

The PlantingScience teachers were given survey instruments and a perceptions of technology interview at the beginning of the workshop with the intent of understanding how well teachers' incoming perceptions and practices predict their levels of reception of the summer workshop. The level of reception of the summer workshop was measured using interview data. These instruments were also used to predict the teachers' levels of classroom implementation of the intervention.

Michael sees himself as an effective teacher capable of recognizing effective teaching strategies (STEBI=0.90). He believes that an increase in support and training maybe likely to help him become a more effective teacher (CBAT=0.95). He recognizes the importance of implementing reform-based curricula (MBPS-import.=0.96) and attempts to implement such curricula in his classroom (MBPS-freq.=0.77). However, he reports feeling less prepared to do so (MBPS-prep.=0.74).

Michael completed the pre-technology survey which was designed to understand the teachers' perceptions of technology and innovative technology use in the classroom. He attempts to use inquiry methods as often as possible through the use of activities in the classroom. He feels that technology helps keep students focused and interested in learning the material. He also reports that his students learn to use technology quickly. His classroom has a projector which is used to deliver content via PowerPoint presentations. Each student has a school issued laptop. Therefore, most laboratory data can be collected via Premier Probes and imported into Excel workbooks enabling for technology to play a large role in student learning. An advantage to using technology in the classroom is faster and more efficient data collection. Students often analyze data in groups and then compare their analysis as a class. Michael would like to use technology to increase collaboration and communication with other students outside of their classroom and school and increase connection to the real world. This would allow students to become more accountable for the knowledge they are discussing. In order for his students to have these types of experiences, Michael would have to increase his planning time. It is mandatory for him to make sure that his use of technology is aligned with state and nation standards because that is how his school assigns grade. Overall, his school supports the use and integration of technology in the classroom.

Michael completed interviews at the end of the workshop which were designed for feedback and to find out about teachers' levels of reception of the workshop. These interviews looked at perceptions of technology use in the classroom and barriers to implementation.

At the conclusion of the workshop, Michael desired to increase use of imaging techniques, especially time lapse, in his classroom and become more proficient at using Excel. He feels he will be successful in implementing every aspect of the PlantingScience workshop since each student is issued their own laptop. The challenges he foresees during implementation are time and lack of planning on his part and money if new equipment is needed. He looks forward to increasing student collaboration, conducting peer reviews, and exposure scientist mentors through the use of the PlantingScience curriculum.

The largest barrier Michael foresees is integrating the PlantingScience curriculum with his state standards since grades at his school revolve around the standards. His administration, parents, and other teachers are generally supportive of implementing innovative curricula in the classroom.

Michael's Implementation:

Michael implemented the PlantingScience project on photosynthesis using the leaf flotation laboratory. He began the sequence of lessons by having his students recall any prior knowledge they had gained about leaves through classroom discussion or experimentation. As students shared their prior knowledge, Michael asked many probing questions to get them to clarify and more clearly articulate their ideas. He used an oversized model of a leaf to help students identify and examine the role of various organelles within the leaf. Michael asked the students to set-up a simple chromatography experiment so they could see the separation of the chlorophyll within a leaf.

He augmented the sequence through the introduction of a phenol red experiment. He had students blow through a straw into water containing the pH indicator phenol red. As the students blew carbon dioxide into the water, the pH of the water changed from neutral to acidic resulting in a color change from red to yellow. Students were hesitant to participate in this experiment. It was interesting to see each of them struggle with making the decision to blow into the solution. Eventually, each student did so and seemed to enjoy watching the reaction take place. The phenol red experiment was used to segue into a discussion of the reactants for photosynthesis.

Day one was basically an introduction to the content that was going to be integrated within the experiment s that the students were going to conduct. Most introduction days in Michael's classroom are spent using direct instruction. This is because the class is composed of students of all grade levels (9^{th} thru 12^{th}) and academic abilities (remedial to honors). As the sequence of instruction progressed, classroom instruction was most commonly shared between the instructor and students.

Day two began with time for reflection as students were asked to write up the procedure for the phenol red experiment. Michael asked the students many guiding questions as they worked on their write-ups. These questions were designed to get students to think about the quality of the information they were including in their write-up. He often encouraged them to reflect and critically analyze their procedure and interpretation of results during this time.

As Michael began the overview of the laboratory procedures, he related the photosynthesis reaction to both the phenol red experiment and the leaf model. He spent a few minutes going over the steps involved in the experimental procedure for removing the air from the leaves (infiltration of the leaves). He then let the students use the remainder of class time to practice the infiltration as they made preparations for the next day's experiment.

Day three began with a brief summary of the experimental procedure based on observations from day two troubleshooting. Students spent the majority of time working in small groups completing the experiment. All groups followed the same experimental procedure, but because a variety of leaves were used throughout the class different results were obtained and discussed amongst the groups. Michael supervised the class and provided assistance with interpretation of the procedure or technique as necessary. The class ended with him providing encouragement and caution as the students began thinking about planning their own experiments.

Michael had support from his administration and other teachers. In fact, some of his co-workers expressed interest in attending the 2009 PlantingScience workshop. Michael stresses the importance of attending the summer workshop for exposure and practice of the curriculum as a reason for his successful implementation. His school is used to implementing innovative curriculum, as they have their student body set-up in various learning communities. As a result, many outside observers come in and out of the classroom throughout the year. Therefore, the students were very comfortable with having graduate student researchers and the video camera in the classroom. As of this implementation, Michael was not able to integrate imaging techniques into the classroom. Michael still reports that he would like more time to devote to planning and practicing before implementation with the equipment and materials available at his school. He believes a video blog to demonstrate techniques may help make implementation easier.

Since all students had their school issued laptops, integration of technology and the PlantingScience curriculum into Michael's classroom was generally successful. Michael implements many types of hands-on activities in his classroom, therefore students were proficient in gathering materials, safety equipment, setting up experiments, and collecting data. Students are also used to coming in and getting straight to work, enabling Michael to make full use of his instruction time. This made the implementation of the PlantingScience experiments a routine part of their classroom experience. Students struggled with the open-ended nature of Michael's responses to their questions regarding the procedure and analysis and get frustrated with his "lack of answers." Many of the students seem interested in the experiment and are willing to share their results with the graduate student researchers. One concern regarding student groups is the ability to move group members after initial set-up in PlantingScience website. Michael felt it was essential to let some groups change composition to help improve group dynamics.

Lesson 1 (MH1): Inquiry Sequence on Photosynthesis

Lesson Flow

Students were active learners (levels of P&I = or > 3) for 71.3% (= 3, 78.6%) of the 45-minute class as they worked individually to complete the online pre-survey (7.1%)

and reported results of small group discussion regarding the purpose of leaves (7.1%). Michael lead discussions and activities to increase student understanding using a leaf model (23.4%), chlorophyll chromatography (16.7%), and the phenol red experiment (23.8%). Passive learning therefore occurred about 21.4% of the time.

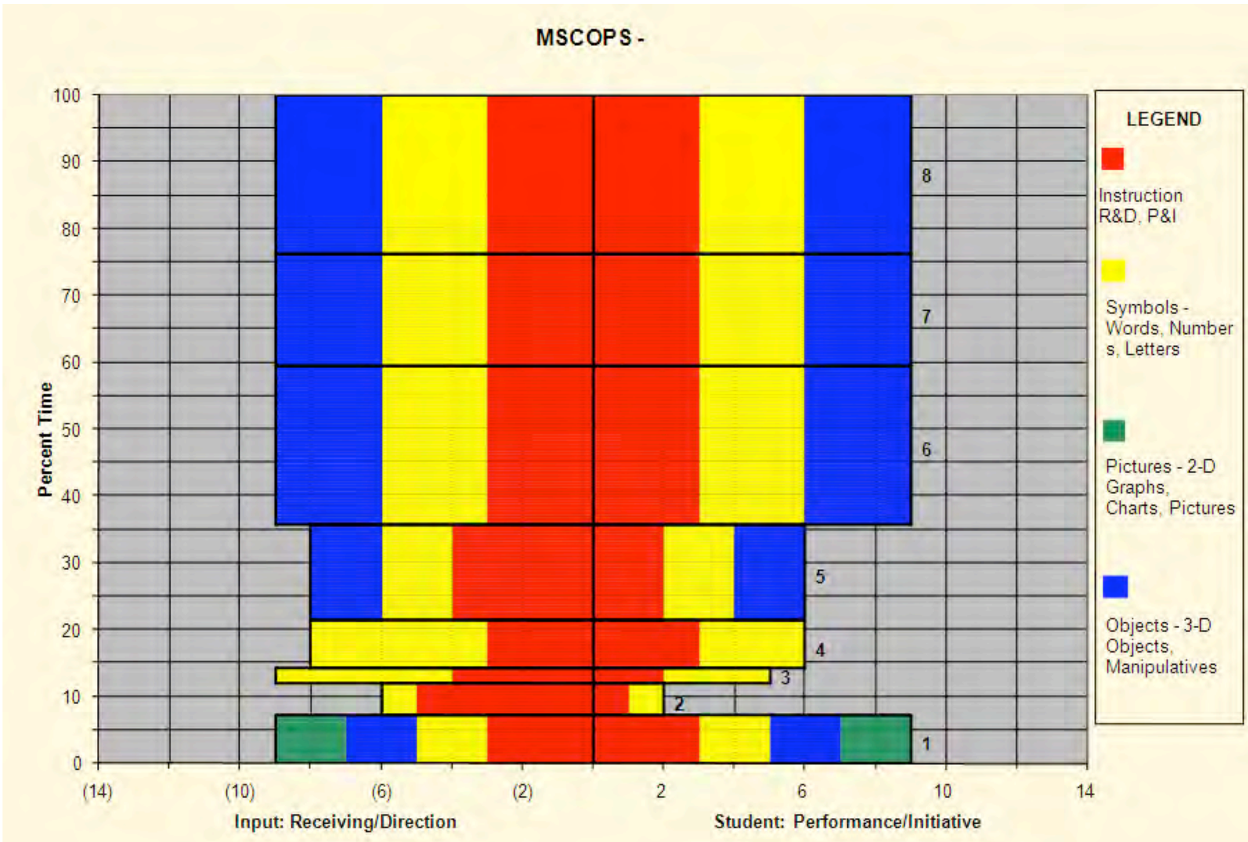

Figure 4. MSCOPS profile for Michael Day 1.

Students' Engagement with Verbal, Pictorial, and Symbolic Information

Students' interactions with verbal information are summarized in Table 7. Class began with students attempting to log onto the PlantingScience website to take their pre-survey (Symbol level 2; Object level 2; Picture level 2). Since the website was not working correctly, Michael instructed the students to put away their laptops and began instruction with having students recall prior experiences with leaves (Symbol level 1). In small groups, students were asked to discuss (symbol level 5) to what they recalled as the purpose of leaves (Symbol level 3). After allowing time for groups to collect their thoughts, Michael began asking each group to report their answers and asked follow-up questions (Symbol level 5) and the students replied (symbol level 3). He used these answers to transition into a lecture about more complex leaf anatomy, the role of various organelles, and the process of photosynthesis (Symbol level 2; Object level 2). Michael then handed out leaves from various plants growing around the classroom and asked students to observe and quantify various leaf qualities and to discuss a method for getting the chlorophyll out of the leaf (Symbol level 3; Object level 3). Michael then led a discussion regarding the method for which to extract chlorophyll and students began conducting the procedure (Symbol level 3; Object level 3). Class ended with students conducting the phenol red experiment to draw connections with photosynthesis and respiration (Symbol level 3; Object level 3).

Table 7

Levels of students' interactions of receiving and acting on symbolic information during Michael's first lesson

Levels of Symbols	Receiving % Time	Acting % Time
1	4.76	4.76
2	21.43	21.43
3	64.29	73.81
4	0.00	0.00
5	9.52	0.00
6	0.00	0.00

Students spent most of the class acting (73.81%) at a complexity level of three through discussions and laboratory activities where they were presented with level 5 (9.52%) and level 3 (64.29%) symbolic information. Students received and acted at a level 2 for 21.43% of the time when they were using the PlantingScience website and learning about the leaf mode. They received information and acted on it a level 1 for 4.76% of the class while they received information about leaves.

Table 8
Percentages of time that students received and acted on objects and pictures

		% Time
Objects	Received	85.71
	Acted On	85.71
Pictures	Received	7.14
	Acted On	7.14

Students received and acted on objects for equal times throughout most of the class period (85.7%). Students received and acted on pictures for equal times during 7.1% of the class period.

Summary

This lesson seemed to be designed to recall students' prior knowledge about leaves and engage them in the new material about photosynthesis. Since this was the introductory day of the lesson, most of the class was spent in teacher-led discussion and explanation through the use of shared learning activities. Introductory lessons are often primarily teacher directed due to the fact that the class is composed of 9th-12th graders. However, Michael tried to engage the students using many different methods throughout the class. Students were provided with a variety of aids to increase their engagement (e.g., leaves, leaf model, PowerPoint presentation, hands-on experiments).

Lesson 2 (MH2): Inquiry Sequence on Photosynthesis

Lesson Flow

This 45-minute lesson was observed as the second lesson in an inquiry unit on photosynthesis. The class began with instructions and guidance on how to write up the phenol red experiment from day one (20 min). This was followed with a discussion of leaf anatomy and a detailed discussion of experimental procedure (11 min). Students ended the class with a few practice trials of the leaf infiltration (11 min). (See Figure 5.)

Levels of Reception and Direction (R&D) vs. Performance and Initiative (P&I)

Students were active learners (levels of P&I = or > 3) for 20.9% (= 3, 20.9%) of the 45-minute class as they worked in groups to practice their laboratory technique for the next day's lesson. Passive learning therefore occurred about 79.1% of the time.

Students' Engagement with Verbal, Pictorial, and Symbolic Information

Class began with students listening to instructions regarding the format and content for writing up their experiment from the day before (Symbol level 1). As they were working on their write-up Michael asked many guiding questions, provided prompts for reflections, and helped guide them to interpret their procedures and results (Symbol level 3; Object level 3). The discussion of the leaf flotation experiment began with a model to describe leaf anatomy and its relation to photosynthesis (Symbol level 2; Object level 2; Picture level 2). Students ended the class conducting practice trials following the experimental procedure (Symbol level 2; Object level 2).

Table 9 indicates that students spent most of the class receiving and acting on symbolic (i.e., verbal) information at a complexity level of two (53.49%) through discussions of leaf anatomy and experimental procedure followed by practice trials. Students received and acted at a level one for 4.65% of the time as they listened to the directions for the write-up of the phenol red experiment. Students received and acted at a level three for 41.86% of the time when they were working on writing up the experimental procedure, data collected, and analysis of the phenol red experiment.

The summary presented in Table 10 indicates that students received and acted on objects for equal times throughout most of the class period (95.3%). Students received and acted on pictures for equal times during 25.6% of the class period.

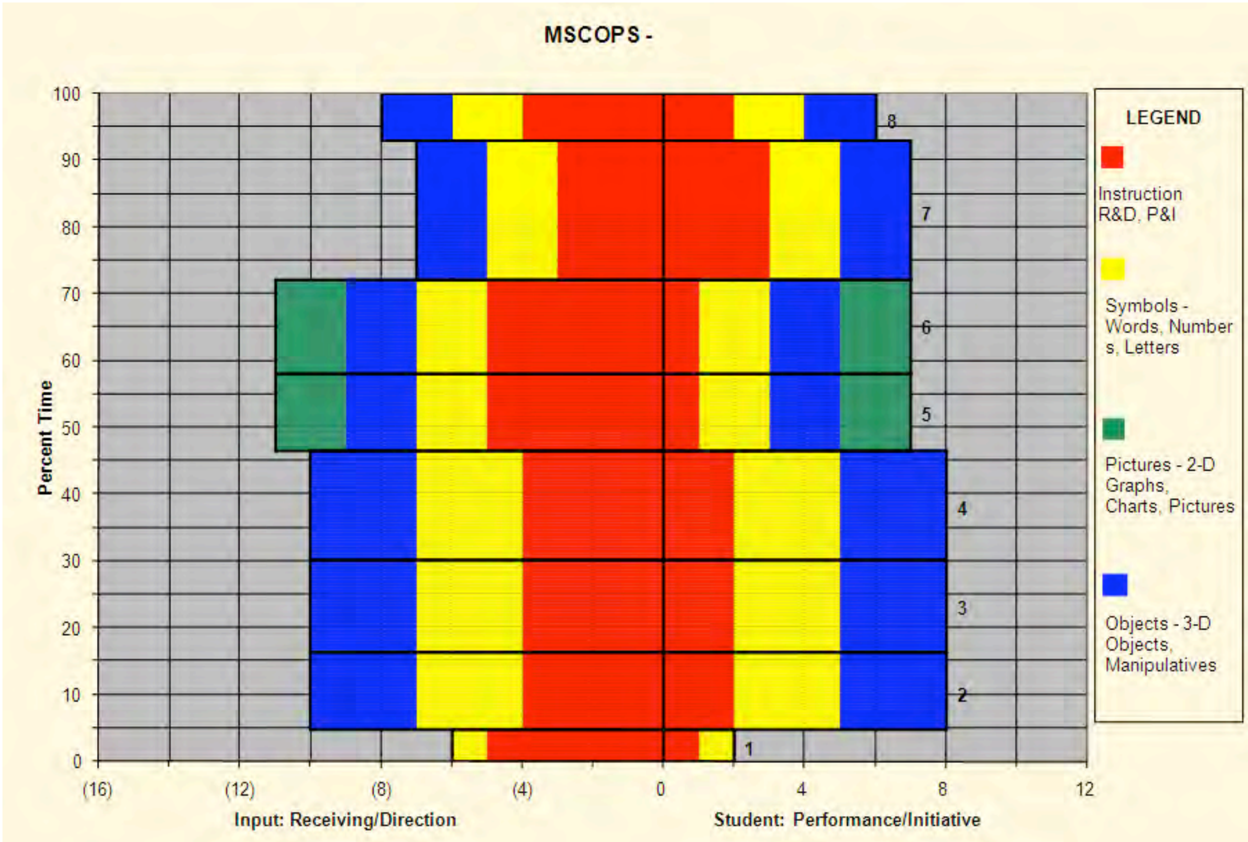

Figure 5. MSCOPS profile for Michael Day 2.

Table 9
Percentages of time students spent receiving and acting on verbal information at different complexity levels

Levels of Symbols	Receiving % Time	Acting % Time
1	4.65	4.65
2	53.49	53.49
3	41.86	41.86
4	0.00	0.00
5	0.00	0.00
6	0.00	0.00

Table 10
Percentages of time that students used objects and pictures during Michael's second class

		% Time
Objects	Received	95.35
	Acted On	95.35
Pictures	Received	25.58
	Acted On	25.58

Summary

Students seem engaged in discussion throughout class. They made many attempts to answer Michael's questions regardless of "correctness." The use of the phenol red experiment to create engagement and provide additional resources for the students to draw connections with the content seemed like a successful addition to the sequence of instruction. Time for student practice at infiltrating the leaves was viewed as an important step for the successful implementation the following day.

Lesson 3 (MH3): Inquiry Sequence on Photosynthesis

Lesson Flow

This 45-minute lesson was observed as the third lesson in an inquiry unit on photosynthesis. The class began with a review of photosynthesis and the teacher's directions for a leaf flotation experiment (7 min) in order to prepare students for the day's experiment. The teacher asked that students generate explanations and hypotheses regarding their observations during the experiment. Groups of students then went to the laboratory where they discussed their results and generated hypotheses as they performed the experiment (34 min). The lesson ended with a short question-and-answer period and group time with the teacher (3 min) that focused on explanations and questions about the experiment. (See Figure 6.)

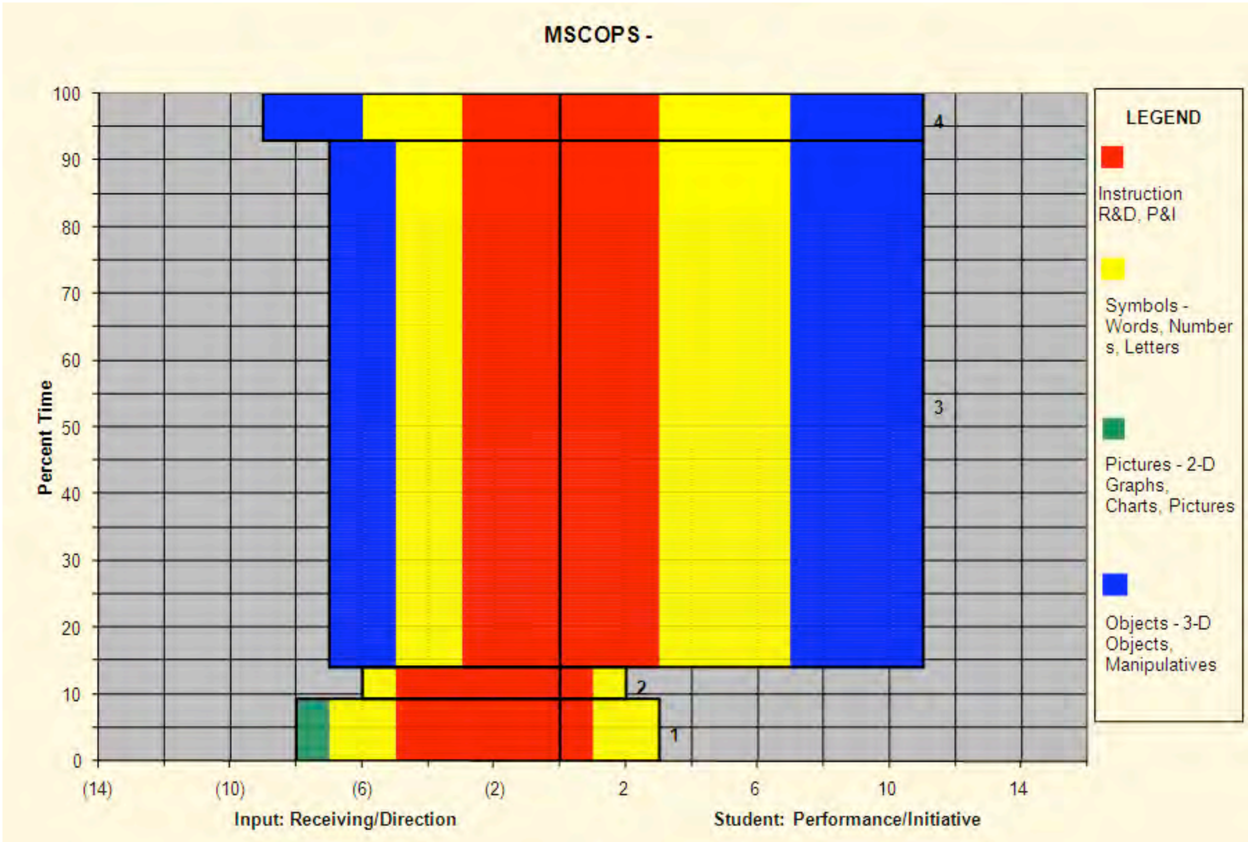

Figure 6. MSCOPS profile for Michael Day 3.

Levels of Reception and Direction (R&D) vs. Performance and Initiative (P&I)

Students were active learners (levels of P&I = or > 3) for 86.1% (= 3, 86.1%) of the 45-minute class as they worked in groups to do the laboratory experiment (79.1%) and talk informally about their results (7.0%) with the teacher at the end of class, respectively. Passive learning therefore occurred about 13.9% of the time.

Students' Engagement with Verbal, Pictorial, and Symbolic Information

Individual students passively observed (picture level 1) and recalled information (symbol level 2) as they listened to the teacher's introductory and closing remarks about the processes of photosynthesis. Students then listened to a summary of the leaf flotation procedure (symbol level 1) Groups of students then carry out leaf flotation procedure and exchanged explanations and hypotheses while in the laboratory (Symbol level 4; Object level 4) as the teacher provided clarification regarding the experimental procedure (Symbol level 2; Object level 2). At the end of class the teacher provided encouragement regarding the experiment and the impact it may have on the design of their own experiments (Symbol level 3; Object level 3). Groups of students also had opportunities to ask and answer questions about their hypotheses of the teacher at the very end of class for a very short period of time as the teacher visited informally with students (Symbol level 4; Object level 4). (See Table 11.)

Table 11
Students' time engaged in receiving and acting on symbolic information at different complexity levels

Levels of Symbols	Receiving % Time	Acting % Time
1	4.65	4.65
2	88.37	9.30
3	6.98	0.00
4	0.00	86.05
5	0.00	0.00
6	0.00	0.00

Students began the class receiving and acting on level two symbolic information listened to a summarization of the previous days content and experimental procedure (9.30%). Students spent most of the class acting (86.05%) at level four symbol through laboratory activities where they were presented with level 2 (88.37%) and level 3 (6.98%) symbolic information. Students received and acted at level one for 4.65% of the time when they were listening to changes to the experimental procedure for day three.

Table 12 summarizes time spent by students in interacting on objects and pictures. Students received and acted on information from objects for equal amounts of time (86.0%). The information from pictures was received for 9.3% of the lesson, but was not acted on (0%).

Table 12
Percentages of time students spent interaction with objects and pictures in Michael's third lesson

		% Time
Objects	Received	86.05
	Acted On	86.05
Pictures	Received	9.30
	Acted On	0

Summary

Students primarily worked in groups during this class after a brief review of photosynthesis and procedures for the day's laboratory work, which was an experiment that uses leaf flotation techniques to observe gas exchange during photosynthesis. The focus of this lesson was on scientific experimentation, explanation, and hypothesis generation about gas exchange in photosynthesis.

Implications

The National Science Education Standards outline the fundamental abilities and concepts that underlie the content standards, which include the abilities necessary to do scientific inquiry (pp. 175-176). These include abilities to

- Identify questions and concepts that guide scientific investigation;
- Design and conduct scientific investigations;
- Use technology and mathematics to improve investigations and communications;
- Formulate and revise scientific explanations and models using logic and evidence;
- Recognize and analyze alternative explanations and models;
- Communicate and defend a scientific arguments.

PlantingScience was designed to supports students in the development of these fundamental abilities. The total of six lessons taught by these two teachers indicate sophisticated orchestration of introductory lessons associated with inquiry. M-SCOPS analyses indicate that teachers provided opportunities for high school students to work at times under the appropriate guidance (rather than direction) of the high school science teacher in an inquiry-mediated learning environment. Fluctuations in levels of complexity in the presentation and assimilation of verbal, pictorial, and object-based information indicate a logical flow of "moves" that prepare students to make decisions, deliberate, and draw conclusions on their own. In our opinions, the excellent training these teachers received by 2008 workshop presenters associated with PlantingScience enabled them to make changes to fit the learning needs of their students and the contexts in which they teach.