Caltech Precollege Science Initiative (CAPSI)
Inquiry Institute Evaluation

Three-Year Summary

2006 - 2008

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Executive Summary

The Caltech Precollege Science Initiative (CAPSI) was founded in 1985 as a collaborative effort of Caltech scientists and the Pasadena Unified School District to initiate a K-6 program of hands-on inquiry science in the schools. CAPSI's work has evolved from elementary to middle to high school as it focused on the progression of inquiry-based science. Students in urban high schools that are predominately low income or minority often learn little science and have poor literacy skills. It has become clear that learning science, as well as literacy skills, through students' own investigations, not by rote learning from a textbook, is most effective for them, and CAPSI wants to encourage that.

The CAPSI Inquiry Institute had a dual function: To expose teachers to the personal experience of learning by inquiry and to make explicit the opportunities for improving students' literacy with inquiry science instruction. With those foundations, ongoing professional development activities will build teachers' expertise in bringing inquiry teaching and symbiotic literacy learning to their classrooms.

In three summers, the CAPSI Inquiry Institute helped 67 high school science teachers from 38 school districts to learn through their own inquiries and to plan to use inquiry science in their classrooms to improve science learning and literacy skills. Participants were recruited through mailings and an ad in the CSTA newsletter, *California Classroom Connection* , and it was advertised at the California Science Teachers Association (CSTA) conference. The Institute began as a four-week experience on the Caltech campus with a stipend of $2500 that evolved to $1,000 and three weeks during later years. At the Institutes, each of three strands was taught in one of Caltech's teaching labs, and was related to the high school curriculum and the California and National Standards:

- Physics - force, motion, and electric circuits;
- Biology - molecular genetics;
- Chemistry - synthesis and analysis of organic compounds.

In each strand, a team of one or two master inquiry high school science teachers and one or more Caltech instructors from the lab courses designed the course and provided instruction. Instructors modified the Caltech lab experiments to be more inquiry-based, simplified them based on time constraints, and created presentations to teach new concepts in support of the lab work. All strands emphasized the use of laboratory notebooks, modeling their use in inquiry science teaching and as tools for literacy.

Public *Works,* Inc., a nonprofit evaluation firm, served as the external evaluator, providing both formative and summative evaluation in Year 1, 2 and 3. The evaluation included pre-/post-surveys of teaching attitudes, tests of content knowledge, and focus groups. Some questions were asked regarding participants' opinions of their teaching abilities and school situation as well as their confidence and preparedness to teach high school science. From their responses it was clear that they were a self-selected group of strong teachers.

A pre/post assessment was administered each year devoted to content knowledge. Each strand answered questions designed by the instructional team and specific to their subject matter, and representative samples are presented in this report. The test scores showed large

gains in content knowledge that attested to the teachers' effective inquiry learning and the instructors' skillful guidance.

Each summer Public *Works*, Inc. conducted focus groups of the participants in each strand. These are reported in detail below. One of the main findings across strands was the enjoyment by participants of the collaboration and interaction with other science teachers. Rarely do these teachers have the opportunity to meet with others who teach the same subject across districts and schools. All strands reported enjoying being in the position of a student and being back on a university campus. The most significant areas for improvement across strands was more clarity of expectations and more of an emphasis on how to transfer inquiry-based instruction to the high school classroom.

The Institute was an overall success. Participants enjoyed their time on the Caltech campus, and learned a great deal about science and inquiry-based learning. Some of their inquiries were translatable to the classroom, but mainly they came away with new ideas for improving instruction through inquiry.

Introduction

The Caltech Precollege Science Initiative (CAPSI) was founded in 1985 as a collaborative effort of Caltech scientists and the Pasadena Unified School District (PUSD) to initiate a K-6 program of hands-on inquiry science in the schools. Begun on a small scale, the program was expanded during the three subsequent years to include the entire district of over 10,000 students in 23 elementary schools. This scale-up, with National Science Foundation (NSF) support, became a model for the NSF Local Systemic Change Initiative. In the 1990s, many educators from across the U.S. and overseas visited the program, observed classes, and consulted with the leaders on how to implement their own programs, many of which became successful district-wide efforts. At that time, CAPSI and the Pasadena schools collaborated to win the first NSF Center Grant for Teacher Enhancement, to work with fourteen predominantly minority school districts in California in establishing inquiry-based K-6 programs.

CAPSI expanded its activities into the development of both preservice and inservice science content courses for elementary teachers in the late 1990s, to help teachers support inquiry learning through students' own investigations. These were successful in a variety of school districts across the nation and in Los Angeles area colleges. In addition, scientists and engineers in France, Estonia, and Columbia have built on the CAPSI model of collaboration with educators to begin to implement national hands-on inquiry science programs in their own countries.

CAPSI's experience in helping to establish district-wide science programs, and in coping with the problems of sustainability led to a study of the issues related to sustaining K-6 inquiry science programs. This initial research effort grew to encompass a variety of other studies related to the practice of science education. CAPSI's work evolved from elementary to middle to high school as it focused on the progression of inquiry-based science. Students in urban high schools that are predominately low income or minority often learn little science and have poor literacy skills. It has become clear to CAPSI that learning science through students' own investigations, not by rote learning from a textbook, is most effective and is much needed in high school classrooms. The Capsi Summer Inquiry Institute was conceived to help teachers meet that need.

For adolescents, particularly second language learners and low SES students, learning literacy through inquiry science is a powerful strategy. In learning science by inquiry, students work with partners and hone their oral literacy skills. Learning scientific vocabulary and the use of evidence-based reasoning is an essential part of the process. An important component also is the science notebook, which mirrors the culture of the professional scientist. In it is a coherent account of the investigation, from the initial question, through the procedures and the data gathered, to evidence-based conclusions. The notebook supports the creation of written and oral reports designed to effectively communicate results to others, using software and hardware technology for graphical displays and data analysis.

The CAPSI Summer Inquiry Institute

The CAPSI Inquiry Institute had a dual function: To expose teachers to the personal experience of learning by inquiry and to make explicit the opportunities for improving students' literacy with inquiry science instruction. With those foundations, ongoing professional development activities will build teachers' expertise in bringing inquiry teaching and symbiotic literacy learning to their classrooms.

Unlike many summer programs, the Institute was not intended to provide teachers with materials to use in their classrooms. It was intended to provide them with the experience of learning through their own inquiry that almost none of them had in the typical lecture-based college courses with cookbook labs. This personal understanding could provide a foundation for change to teaching through inquiry. At the Institute, each of three strands was adapted from one of Caltech's teaching labs and also related to the high school curricula and the California and National Standards:

- Physics - force, motion, and electric circuits
- Biology - molecular genetics
- Chemistry – synthesis and analysis of organic compounds

During its three years, the CAPSI Summer Institute helped 67 high school science teachers to learn through their own inquiries and to plan to use inquiry science in their classrooms to improve science learning and also literacy skills. After the intensive summer Inquiry Institute at Caltech, CAPSI supported their ongoing efforts as a learning community to effect classroom change during the year through follow-up workshops, classroom visits, and email support.

- Participants were recruited through mailings and advertisements in print and at the California Science Teachers Association (CSTA) conference. The Institute began as a four-week experience at the Caltech campus with a stipend of $2,500 with 50 % to be paid by the school district. In cases where the district did not contribute, CAPSI did. In successive years a simple stipend of $1,000 was offered. Making up for salary which could come from teaching in summer school was not feasible. In the final year a database of teachers was purchased to allow us to reach them directly. The response was never enough to fill the 16 places in physics and chemistry. Shortening the Institute to three weeks during the final year did not change things.

- In each strand, a team of one to two master inquiry high school science teachers and one or more Caltech instructors from the lab courses designed the course and provided instruction. The team thus combined expertise in both content and pedagogy. Instructors modified the Caltech labs to be more inquiry-based, simplified them based on time constraints, and created lectures and presentations to teach new concepts in support of the lab work. All strands emphasized the use of laboratory notebooks including their use in inquiry science and as tools for literacy.

Evaluation

Public *Works,* Inc. (PW), a nonprofit evaluation firm, served as the external evaluator providing both formative and summative evaluation in Year 1, 2 and 3 of the Caltech

Precollege Science Initiative (CAPSI). PW is experienced not only in large-scale teacher-student evaluation, but has been involved in National Science Foundation evaluations in the past and understands the research expectation. PW is currently the statewide evaluator for the California Department of Education's California Mathematics and Science Program (CAMSP) evaluating innovative partnerships providing professional development through institutes of higher education to mathematics and science teachers in fourth through ninth grade. PW collaborated with the CAPSI project team to evaluate their Inquiry Institute focused on the professional development of high school science teachers in 2006, 2007 and 2008.

Public *Works*, Inc. developed the instruments used at the Institute and analyzed the data including:

- Pre-Surveys and Post-Surveys of teachers participating in the CAPSI Summer Institute
- Institute Observation
- Focus groups at the end of the Institute with participants and trainers
- Follow-up survey

Summary of Participants

A total of 67 participants attended the Institute, from 28 different districts (as listed in Table 1) across the Los Angeles basin and 53 different schools, over the three-year period, based on the survey. There were 31 teachers in the Biology strand, 19 in the Chemistry strand, and 17 in the Physics strand.

Table 1: Participating School Districts 2006-2008

Anaheim Union	Hacienda La Puente Unified
Arcadia Unified	Inglewood Unified
Bassett Unified	Long Beach Unified
Bellflower Unified	Los Angeles Unified
Centinela Valley Union High	Montebello Unified
Chaffey Joint Union High	Norwalk-La Mirada Unified
Charter Oak Unified	Pasadena Unified
Compton Unified	Pomona Unified
El Monte Union High	Rowland Unified
El Rancho Unified	Saddleback Valley Unified
Fullerton Joint	South Pasadena Unified
Garden Grove Unified	Temple City Unified
Glendale Unified	Torrance Unified
Glendora Unified	Other

Table 2 reports the grade levels the participating teachers taught and Table 3 presents the summary results on teachers' years of teaching, employment status, and teaching credential status. It seems that the Institute appealed more to experienced teachers than beginners, which was not expected.

Table 2: Grades Taught by Participants, 2006–2008 (N= 67)

	Middle School	9	10	11	12

Grades Taught Before Institute	8%	35%	43%	48%	43%
Grades Planning to Teach After Institute	4%	32%	48%	55%	45%

Table 3: Number of Years Teaching and Employment Status of Participants, 2006-2008 (N= 67)

First year of teaching	4%	Permanent	72%	Clear Credential	60%
2nd year	7%	Probationary	15%	Preliminary Credential	31%
3-5 years	25%	Temporary	9%	District/University Intern	4%
6-10 years	25%			Emergency permit/Waiver	0%
11-20 years	22%				
More than 20 years	10%				

Content Learning

A pre/post assessment was administered to all participants devoted to content knowledge each year. Each strand answered questions designed by the instructional team and specific to their subject matter. Tables 4-6 have the representative samples from those tests and scores on them.

Table 4: Biology Content Question Samples from Pre/Post Survey, Summer 2008

	Average % Correct Pre-test	Average % Correct Post-test	Change in Average % Correct
Overall score	**48%**	**90%**	**42%**
What does GFP used for?	15%	100%	85%
How does PCR work?	31%	92%	61%
How does antibiotic selection work?	23%	75%	52%
How does gel electrophoresis work?	46%	96%	50%
In molecular biology, what is meant by a vector?	38%	79%	41%
What is the purpose of gel electrophoresis?	62%	100%	38%
What is a restriction digest?	54%	92%	38%

Table 5: Chemistry Content Question Samples from Pre/Post Survey, Summer 2008

	Average % Correct Pre-test	Average % Correct Post-test	Change in Average % Correct
Overall score	**28%**	**72%**	**44%**
In proton NMR, protons located near electrophilic groups are shifted in which direction?	17%	100%	83%
Draw an example of a triglyceride	27%	96%	69%

Draw the basic NMR splitting pattern of the protons in the ethyl acetate.	0%	65%	65%
Order these solvent systems in increasing polarity: 100% ethyl acetate, 75% hexane/ 25% ethyl acetate, 25% hexane/ 75% ethyl acetate	21%	80%	59%
Draw the ester, ethyl decanoate	23%	64%	41%
Explain exactly how you would make a 2.8M solution of KOH from KOH pellets	33%	58%	25%
Draw an example of a molecule that contains both hydrophobic and hydrophilic parts. Label them.	83%	100%	17%
Define polar vs. nonpolar and hydrophobic vs. hydrophilic. Draw an example of a polar molecule and a nonpolar molecule and label them.	76%	65%	-11%

Table 6: Physics Content Question samples from the Pre/Post Survey, Summer 2008

	Average % Correct Pre-test	Average % Correct Post-test	Change in Average % Correct
Overall score	**42%**	**47%**	**5%**
At the airport, a person forgets to remove a metallic object from his pocket before passing through the metal detector. Explain how the detector detected the object.	36%	55%	19%
A child pumps her legs to maintain a playground swing's motion. Explain the physics behind her action.	40%	55%	15%
A spinning top is observed to "wobble" about the vertical axis. Explain the mechanism of this phenomenon.	36%	49%	13%
When a person goes to the beach it is prudent to apply sunscreen. Why does the same person not use a similar product while watching television?	50%	63%	13%
A soft- spoken high –school principal uses a public address system to speak to an auditorium full of students. Explain the physics that allows a student in the back row to hear the principal.	38%	45%	7%
A yo-yo, wound as shown, is placed on a level surface with sufficient friction to prevent slipping. The string is pulled with a force parallel to the surface. Describe the behavior of the yo- yo.	34%	40%	6%

The major effect illustrated by the biology and chemistry scores was that the teachers learned a great deal of new content from their investigations. They could see that inquiry learning was effective. For the physics participants, the initial knowledge was stronger on the average and the gains were smaller. The instructors emphasized using basic physics in an inquiry context rather than learning new concepts, which resulted from the fact that the subject matter of the Caltech lab course was not very new to them. They very much enjoyed visiting old physics in a new way however.

Opinion Surveys

As part of the pre/post-survey all participants completed, questions were asked regarding participants' opinions of their teaching abilities and school situation as well as confidence and preparedness for teaching high school science. Strengths that were reported across strands were that participants:

- Already enjoyed teaching science
- Significantly gained increased confidence in several content areas
- Felt better prepared to have students communicate their understanding of Science journals or oral presentations.
- Learned some effective strategies
- Could designs lessons for optimal student learning

Participants in the Institute considered themselves "master" science teachers and felt that students learn best in classes with students of similar abilities (See Table 7). Participants explained that science teachers at only a few schools regularly observe each other teaching classes as part of sharing and improving, and most science teachers in such schools contribute actively to making decisions about science curriculum.

Table 7: Participant Average Opinions from Survey, 2006-2008 (N= 67)

Please provide your opinion about each of the following statements **1=Strongly Disagree 2=Disagree 3=No Opinion 4=Agree 5=Strongly Agree**	Average Opinion
I enjoy teaching science	4.7
The testing program in my state/district dictates what science content I teach	3.8
I consider myself a "master" science teacher	3.3
Students learn science best in classes with students of similar abilities	3.2
Most science teachers in this school contribute actively to making decisions about the science curriculum	3.0
I have time during the regular school week to work with my colleagues on science curriculum and teaching	2.6
Science teachers in my school regularly observe each other teaching classes as part of sharing and improving	2.0

Participants felt prepared to take students prior knowledge into account when planning lesson and lectures, to balance teaching concepts with skills and procedures, and the use evidence of student work to make instructional decisions (see Table 8). Teachers are now more inclined to incorporate math into their lessons by teaching mathematical problem solving and reasoning and to integrate math with other disciplines. There was as strong increase in teachers having students communicate their understanding of science in oral presentations and journals, and the use of effective questioning strategies.

Table 8: Participant Average Opinions from Survey, 2006-2008 (N=67)

How well PREPARED do you currently feel to do each of the following in your science curriculum? **1=Not at all 2=Need to Prepare 3=Sometimes 4=Prepared 5=Very Prepared**	Average
Teach mathematical problem solving and reasoning	4.2
Teach groups that are heterogeneous in ability	4.2
Have students work in cooperative learning groups	4.1
Have students communicate their understanding of science in journals or oral presentations	4.0
Take students' prior knowledge into account when planning curriculum and	4.0

instruction	
Use effective questioning strategies	3.9
Use evidence from student work to make instructional decisions	3.9
Integrate math with other disciplines	3.9
Teach students who have limited English proficiency	3.9
Balance teaching concepts with skills & procedures	3.9
Use the textbook as a resource rather than the primary instructional tool	3.9
Design lessons for optimal student learning	3.8
Teach students who have special needs	3.7

The 2008 participants reported that they mainly introduce content through formal presentations. Students are also asked to use multiple representations in their science class more than the participants in 2006 and 2007. Some have students write reflections such as a journal where discuss what occurred in their science class and allowing students to design their own activity or investigation. Tables 9-10 have more detailed results.

Table 9: Participant Average Opinion on Survey, 2008 (N_{2008}= 26)

About how often do you DO EACH OF THE FOLLOWING in your in science instruction? 1=Never 2=Rarely 3=Sometimes 4=Often 5=All/Almost All	2008
Assign science homework	4.0
Introduce content through formal presentations	3.8
Require students to explain their reasoning when giving an answer	3.8
Encourage student-to-student interaction (questioning, explaining concepts)	3.7
Help students make connections between mathematics, other disciplines, and the real world	3.7
Anticipate student misconceptions or expected student response before a lesson	3.7
Pose open-ended questions	3.5
Engage the whole class in discussions	3.4
Use questioning to help students consider alternative methods for solutions	3.4
Ask students to use multiple representations (e.g., numeric, graphic, etc.)	3.4
Allow students to work at their own pace	2.9
Read and comment on the reflections students have written, e.g. in their journals	2.9

****Similar responses were found in 2006 & 2007***

Table 10: Participant Average Opinion on Pre-survey, 2008 (N_{2008}= 26)

About how often do STUDENTS in your science class do the following? 1=Never 2=Rarely 3=Sometimes 4=Often 5=All/Almost All	2008
Design their *own* activity or investigation	3.9
Listen and take notes during presentation by teacher	3.8
Read non-textbook science-related materials in class	3.8
Write reflections (e.g. in a journal)	3.8
Read from a science textbook in class	3.7
Follow specific instructions in an activity or investigation	3.6
Work in groups	3.5

Question or share ideas with each other	3.5
Practice routine computations/algorithms	3.5
Use calculators or computers for learning or practicing skills	3.5
Engage in math activities using concrete materials	3.4
Record, represent, and/or analyze data	3.4
Use science concepts to interpret/solve applied problems	3.3
Answer textbook or worksheet questions	3.2
Make formal presentations to the rest of the class	2.9
Work on extended science investigations or projects (a week or more in duration)	2.9
Review homework/worksheet assignments	2.8

****Similar responses were found in 2006 & 2007***

From the responses in the preceding two tables (Tables 9-10), these were not on average passive or routine about their work and their students' involvement in their learning. They were clearly a self-selected group with strong teaching skills. Fertile ground for introducing inquiry teaching.

With regard to the Institute, questionnaires showed that across strands participants were very highly satisfied with the facilities, the food, the trainers and facilitators, time and activities across disciplines, groups, and individual instructors. Participants felt that the other participants had an impact on their work. Participants were pleased with the materials used, the content, and the length of time each day and time if the overall institute. Participants were least satisfied with the effectiveness of the focus on ELL/Literacy Issues and the follow-up plan for the next school year. The qualitative analysis

Participant Focus Groups

Every summer Public *Works*, Inc. conducted a focus group of participants with each strand: Biology, Chemistry, and Physics. Teachers reported being recruited as participants from multiple sources including letters, conferences (i.e. CSTA) and emails. One of the main findings across strands was the enjoyment by participants of the collaboration and interaction with other science teachers. Rarely do these teachers have the opportunity to meet with others who teach the same subject across districts and schools. All strands reported enjoying being in the position of a student and being back on a university campus. The most significant areas for improvement across strands was more clarity on future expectations and more of an emphasis on how to transfer inquiry based instruction to the high school classroom.

Biology

In the focus group, Biology teachers focused on the importance of being exposed to new labs, new information, and new content such as biotechnology and microbiology. The use of new and state of the art equipment in the labs was something they would not have had access to without the Institute. Modeling of inquiry-based teaching with open-ended analysis changed the way many teachers thought about their own instruction. Many

One teacher about modeling the inquiry process said, "I will be one more resource person in the room and constantly say 'well what do you think' to students." Another said, "we are always trying to force a right answer."

teachers described that they never had these types of experiences before in such an open-ended format.

Teachers focused their comments on how important it was to be with a group of teachers at the Institute that were enthusiastic and committed to the content and the love of learning in biology. “When we didn’t know, we were forced to think. We were students—questioning and collaborating.” Teachers felt there was so much support for learning with no judgment.

Teachers were very satisfied with their facilitators—“they were excellent.” They felt that they were treated as if they were post doctorate students with no breaks and an expectation to understand. “We were immediate learners with pressure and challenges. It was not threatening. Facilitators were patient and safe.” The format was teaching inquiry through inquiry. “It felt like one big project that escalated to the big end.” Teachers appreciated the exposure to on-line resources. This will help students to do research and give new teaching directions.

When asked in the focus group about application to the classroom, teachers felt they were still processing how to incorporate what they learned in the classroom. “My information is in the textbook, but now I have this new way to explain and explore more information on how to apply biology.” The Institute gave new teaching directions—“building in inquiry everyday.” One teacher about modeling the process said, “I will be one more resource person in the room and constantly say ‘well what do you think’ to students.” Another said, “We are always trying to force a right answer.”

When asked what needed to be improved at the Institute, the teachers in the biology group wanted more clear expectations on outcomes. “There were lots of assumptions that we knew what inquiry was and is. We needed more upfront.” Many talked about the need for guiding questions in the labs whereas some just simply wanted to know where they would be each day. It was unclear to teachers if there was a literacy-based or English Learner theme to the Institute.

Teachers wanted more time on how to apply what they learned to their classroom during the Institute. They questioned how they could do inquiry-based instruction with limited resources. Teachers wanted to have time to get together and collaborate on how to make inquiry based learning work in the classroom. “I did think I would come out of the Institute with labs. We need to be given a day to apply what we learn, re-do labs, and swap lessons.” Teachers discussed how they might improve their “cookie cutter” labs where there is a procedure to follow and limited time. Many felt that the ratio of adult to students in the classroom did not allow for inquiry. However, most agreed they were going to try more inquiry-based homework.

Chemistry

The Chemistry teachers were very satisfied with their experience, and in particular enjoyed their labs. They like the amount of time spent in labs, the facilitators, the openness, and their own ability to ask questions. Being at a prestigious university was a real draw for all participants. They loved being on the campus and getting tours to see what research and application was occurring on campus. “It was all so cutting

About the lab experiences, one teacher said, “I had to re-learn the concepts, and in the process I thought that’s why students look at me with dumb faces.”

edge and everyone was so open to talk about it." One teacher had a digital camera his entire time on campus so that he could record campus images into a Power Point to show students. He wants his enthusiasm to be "contagious" for students.

The teachers liked the smallness of their group. It allowed them to have good discussions and stay as a whole group the whole time. About the lab experiences, one teacher said, "I had to re-learn the concepts, and in the process I thought that's why students look at me with dumb faces." Teachers liked that the facilitators did not say "here is the model, but instead we were living the model." Most like the openness and loose structure that prompted inquiry. A few agreed with the sentiment, "inquiry still needs to be more guided with guideposts and expectations."

Some teachers wanted more structure in terms of expectations and schedule. They wanted to be challenged on inquiry, but not on schedule. Others took the lack of a schedule as part of the inquiry challenge. Some were looking for a required product or clarity on what was expected of them. There were some room challenges in what was scheduled.

Teachers thought parts of the labs they were involved in at the Institute could be used directly with their students. However, they realized that the entire point of the Institute was for the teachers themselves to get more comfortable with inquiry in order to bring that process to their classroom. There was some debate on how much inquiry could be brought to their students given the format and time limitations of high school. Most talked about their "cookbook" lab approach with inquiry discussions. They believed it was a time challenge for students to do experiments like figure out the recipe for soap. "Maybe after state testing we could do real inquiry."

Teachers also discussed how student motivation plays a role in how much inquiry you think you can do in the classroom—high end students, more inquiry. There was great range in the number of labs teachers conducted with their students (reported from 8 to 30). Most teachers could design inquiry labs that they now wanted to try in their classroom such as an extraction lab using Monster Drink Full Throttle. Most agreed that the "take aways" from the Institute were different by person, because each person teaches differently.

The teachers observed limited links of what they did in labs to the standards. "We did organic chemistry, but that in Chemistry in schools that is limited," However, one pointed out that these labs can meet the state standards which is allows the resource justification to buy science supplies for their classroom.

When asked about follow-up topics, participants want to spend time on standards alignment mostly in order to justify resources with the need to conduct "low cost inquiry" and to learn what other teachers are doing with inquiry in their classroom. "There needs to be more emphasis on how do we transition this to the classroom with small ideas." This follow-up topic could include discussions on when to focus on coverage and when to focus on depth.

One teacher thought that in year two a participant should be assigned to a real Caltech research project during the school year or over the summer. This internship could give the teacher hands-on experience in research that may help their inquiry based teaching.

Physics

> ***"I have a better understanding of what inquiry is and that it isn't what I thought it was."***

The Physics teachers enjoyed their participation in the Institute, especially in the laboratory experiences. "They challenged me." The labs were experiences that teachers never would have had the opportunity to do without the Institute. Teachers were pleased with the facilitators and the way they were treated as scientists. Facilitators were available to answer questions and guide, but they modeled and encouraged the inquiry process. Teachers needed to work on the problems, and the facilitators did not always give them the answers they wanted. "I got to experience what my students feel."

> ***"I got to experience what my students feel."***
>
> ***"I learned what kind of thinker I am. I am grading students the way I do not want to be graded."***

Teachers spent time together including lunches talking about Physics and teaching. In the focus group, teachers discussed how alone physics teachers are at schools, and how helpful and enjoyable it was to be with "like-minded teachers." Teachers were reflecting together and individually throughout the Institute through discussions and journals.

Teachers spent time in the focus group critiquing or improving labs. For example, teachers suggested that the microscope task could have been focused around a couple of questions for "guided inquiry." However, overall teachers agreed with the sentiment, "I have a better understanding of what inquiry is and that it wasn't what I thought it was." They understood the point to the Institute to model a process of inquiry. "The Institute was not about time to translate what this means for the classroom. That's our job after the Institute." Most agreed with the underlying message of the need to change how teachers approach teaching. The Institute served as a reflection time for teachers on their own teaching. "I learned what kind of thinker I am. I am grading students the way I do not want to be graded."

In applying what they learned, teachers thought maybe the way to improve inquiry in their classroom was first in the selection of the particular labs and trying to re-vamp key labs to be more inquiry based. Teachers wanted to work with their fellow participants to take common labs and revamp them. "I need inspiration from other teachers." There was agreement in the need for more use of journals in a more open inquiry process. "I wanted them to do it my way which is too rigid for inquiry." Most teachers agreed that although their inquiry at the institute could be "true inquiry based," high school students needed to be managed or do limited inquiry. "I like discovery for myself, but I am skeptical if my students can do it." Teachers discussed differing types of students, and how inquiry might be difficult with "frustrated learners." However, they were committed to do more open-ended activities and play games.

Teachers did get a good reminder of what it is like to be a student and what they needed to do for their students. They had forgotten what it was like to see material for the first time, like students do everyday. Teachers described their need to "sell" the content to students, including selling discovery to students who are not used to discovering. Teacher felt excited by the Institute to go back to their students to teach science.

When asked what needed to be improved about the Institute, all agreed "more time with Jerry Pine and learning about his book *Zap!*." Teachers wanted more time with experiments. However, they wanted more time together too. Informal lunches often were "shortened" because labs took too long. They want to share their experiences as teachers. Also, teachers want more computer access in inquiry time—they could not "Google" for support during the labs.

Teachers liked the length of the Institute, and that it did not conflict with summer school. They want to re-convene in a follow-up format. The teachers are working on sharing through the Website they have created.

Conclusions and Recommendations

The Institute was an overall success. Participants enjoyed their time on the Caltech campus, learning a great deal about science and inquiry-based discoveries. Several of the techniques are directly translatable to the classroom, while other changes occurred in the teachers approach and increase in content knowledge. There was improved recruitment throughout the year, which resulted in good participation in each group. A tight knit cohort of teachers was created in each strand with strong facilitators assigned to each.

Clarification of Expectations to Participants
In 2006, 2007 and 2008 participants across strands indicated the participants needed clearer expectations and structure of the Institute at the beginning. While expectations have improved, participants indicated there was room for improvement. In 2008, the participants were more open to the inquiry-based format and the need to experience the inquiry themselves in order to do more in their own classroom. Teachers were less frustrated by the lack of clear definition and explanation of inquiry-based instruction. Participants anticipated acquiring new skills and activities for the classroom as well as adapting their current textbooks and lessons in order to make them more inquiry-based.

Transfer of Knowledge to the High School Classroom
Given that teachers built a strong, collaborative cohort in each strand, teachers wished they had time to share how to apply inquiry the their own classroom. Teachers want to work together on topics, lessons, supplies, homework assignments and other avenues to build in inquiry based on the restrictions of a high school classroom including time, textbooks, standards and budgets. They suggested that these discussions occur in the last week of the institute.

Lessons Learned

The Institute was strengthened in the following areas and over time from 2006 to 2008.

Designation of Leader
Participants suggested the clear designation of a leader for each strand would provide more direction and structure for both teachers and instructors. Respondents indicated this person would not have to attend each activity, but should be apprised of the content of each and work to integrate them into a cohesive whole.

Literacy Program
In 2006 participants and instructors acknowledged that the literacy workshop appeared to be added as an afterthought and was not incorporated into the day-to-day activities. Those questioned in 2007 agreed with the previous year's assessment of the program.

Clarification of Follow-up
In 2006 participants indicated the best way to increase participation in follow-up activities was to include these activities as expectations for the Institute from the beginning. Teachers suggested they be conducted in the middle of the school year rather than towards the end. Their feedback was taken into account with site visits and surveys.

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