

# IMPACT OF A K-12 PARTNERSHIP ON SCIENCE TEACHING

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## ABSTRACT

The Collaboration to Advance Teaching Technology and Science (CATTS) program supports a variety of partnerships that bring faculty and students at the university level together with K-12 teachers and their students to promote short- and long-term research projects as well as inquiry science and mathematics lessons in K-12 classrooms. Our goal is to improve science, mathematics and technology education in grades K-16. Continuous program evaluation provided critical information about how well the partnerships were developing and their overall impact. We were able to use the results of surveys and journal writings to make important improvements to our preparation workshop and our communication with school partners over the course of our first and second year, and continue to do so. These same instruments provided documentation that the program was having the desired impact on the attitudes and teaching practices of university and K-12 participants. The key to success in all of our partnerships has been the willingness and ability of the university and school partners to communicate their goals and expectations effectively. The lessons learned in designing and implementing the CATTS program can be applied directly to building research or any other kind of partnership with schools.

Keywords: teacher education, graduate education, pre-college education.

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## INTRODUCTION

The Collaboration to Advance Teaching Technology and Science (CATTS) is a partnership between the University of Arizona and local school districts with the goal of improving science, mathematics and technology teaching in grades K-16. To accomplish this goal, CATTS provides education and outreach opportunities for talented undergraduate and graduate students (CATTS Fellows) to gain experience with inquiry-based teaching and in communicating scientific concepts to K-12 students. The Fellows work in partnerships with K-12 educators who share their knowledge of teaching with the Fellows; in return, the educators gain a deeper understanding of scientific inquiry and scientific content by working with the Fellows. Typical partnerships include helping elementary and middle school students and teachers conduct monitoring of soil moisture as part of the GLOBE program, long-term monitoring of an endangered specie, development and implementation of a neighborhood improvement plan, and long-term

recording and analysis of local and global seismicity. A detailed discussion of the CATTS program is contained in a companion paper by the authors, "Building university-school partnerships: An exercise in communication and understanding", published in this issue.

During the first two years, the program has involved 46 CATTS Fellows, more than 123 K-12 teachers, 65 schools and at least 4600 students. "Fellows" are undergraduate and graduate students, who have been awarded a prestigious National Science Foundation Graduate K-12 Teaching Fellowship. They work as an undergraduate and graduate pair to carry out a particular partnership activity. The CATTS program requires Fellows to make an 18-month commitment to building a partnership with teachers. Fellows join the program in the spring and complete a semester-long preparation workshop (Hall-Wallace and Regans, this issue). The workshop provides the Fellows with a foundation in science teaching and in understanding the K-12 formal education environment. This semester workshop is followed by a yearlong commitment by Fellows to work 15 hours each week with one or more classroom teachers on a project. During the fall semester when they are working in the schools, Fellows participate in a one-hour seminar each week to discuss their project and share insights with the other Fellows.

The formative evaluation of a large program is essential but daunting because there are so many components to evaluate and questions to investigate. The key question on which we focused was whether the design, implementation, and management of the program promoted partnerships that resulted in positive changes in K-12 teaching and prepared a future generation of college professors to make similar changes at the college level. To be successful, we expected that:

- CATTS Fellows and participating K-12 teachers would be more knowledgeable and skilled in teaching with inquiry and would use inquiry more frequently.
- CATTS Fellows would have a positive attitude towards teaching and K-12 education. This would result in the Fellows recognizing the need and benefits of scientist-teacher partnerships. We expected that the Fellows would be prepared to participate in these partnerships throughout their career. (Although, promoting careers in K-12 education is not the goal of CATTS, it is not discouraged and a few Fellows have chosen this career after the fellowship.)

Time	Activities of Fellow	Fellow Assessment	Teacher Assessment
Spring Semester (January-May)	Preparation workshop exploring the K-12 education environment	Pre- and post-surveys of Fellows' knowledge and attitudes Journals	Teacher panels Teacher speakers
Fellowship begins (late May)	Assist with teacher professional development workshops Gather resources for classroom use	Journals Weekly logs	Meetings with teachers
Fall Semester (August-December)	Weekly seminar Work in schools 15 hours per week	Journals Weekly logs Post-surveys of Fellows' knowledge and attitudes	Classroom Observations Teacher Panels
Spring Semester (January-May)	Work in schools 15 hours per week	Journals Weekly logs	Classroom Observations
May – End of Fellowship		Exit interview Exit survey	Teachers' Survey

**Table 1: Summary of Assessment Activities Used in the Program**

Research shows that both teachers and students benefit from inquiry instruction. The use of inquiry activities enhances students' interest in science, their motivation to continue studying science, their attitudes toward science, and their view of themselves as practitioners of science (Damjanovic, 1998; Jones, Mullis, Raizen, Weiss, & Weston, 1992; Kahle, 1985; Kahle & Damjanovic, 1994; Levin, Sabar, & Libman, 1991; Huber & Burton, 1995). We assessed knowledge and use of inquiry with surveys, classroom observations and student journal writing.

The role of attitude and future success has been the subject of a considerable amount of research. The result of these studies shows that attitude (e.g., beliefs, self-efficacy) is an important determining factor of future success or interest in a particular domain (Palmer & Neal, 1994; Mittelstaedt, Sanker, & Veer, 1999). Moreover, a positive connection is found between attitude and behavior in many areas (Dressner & Gill, 1994; Leeming, Dwyer, Porter, & Cobern, 1993; Shepard & Speelman, 1985). Because of the important relationship between attitudes and effectiveness, we assessed our Fellows' attitudes three times during our eighteen-month relationship.

Koballa and Crawley (1985) proposed that a negative attitude toward science and science teaching translates into unsuccessful teaching practice in science. In addition, Tosun (2000) argued that an individual's past experience in science courses influence their attitude toward science and science teaching regardless of their achievement in science. His study demonstrated that the responses of both high and low achievement groups revealed a dislike toward science (Tosun, 2000). He argued that science courses should offer a different approach to science teaching as a means of increasing positive attitudes towards science. The approach should focus on providing active participation to promote a positive experience in science.

In developing our evaluation instruments, we have attempted to measure our progress in the areas described above. Both CATTS and research partnerships focus on creating a learning environment that stimulates interest in science, improves understanding of science concepts, and develops attitudes favorable towards science among both the K-12 teachers and students. CATTS has the additional goal of improving scientists' attitudes about teaching and outreach to K-12 schools. The similarity of goals between CATTS and many research partnerships allows the lessons learned in this program to be applied equally well to the more traditional research partnerships.

## EVALUATION PLAN

We used a mix of qualitative and quantitative methods to evaluate our program as recommended by Hannah (1996). This included qualitative journal analysis, quantitative surveys of knowledge and attitudes among the Fellows, and exit interviews. We also gathered both qualitative and quantitative information about the success of the fellowship from participating K-12 teachers and the Fellows at the end of the 18-month period using exit surveys. A summary of assessment activities used in the program is shown in Table 1. We gathered data nearly continuously throughout the program and used them to inform future activities. This process ultimately had a very positive effect on our program, but created some challenges for interpreting our assessment data. These challenges include evaluating the qualitative information from the Fellows, and positively identifying cause and effect relationships when the program structure is constantly changing with new information from the evaluation process. We will review the purpose of each type of assessment instrument used and what we learned about the short and long-term effect of this K-12 partnership.

The Fellows in this study are students seeking degrees in full range of disciplines including geosciences, engineering, computer science, mathematics, physics, toxicology, biology and chemistry. The teachers involved have from one to thirty-two years of classroom experience and are equally divided among elementary, middle and high school grades. In our evaluation of CATTS, we found no correlation between establishing a successful partnership and either the Fellows' field of study or the amount of experience that the teacher partner had in the classroom. Further, even though undergraduate Fellows typically had less experience with scientific inquiry, we found them equally capable of teaching with inquiry since they had fewer bad teaching practices to correct than many of the graduate students. However, the lower maturity levels of undergraduate students did pose problems for some when establishing a partnership.

## STUDENT JOURNAL WRITING

Student journals were the most effective means of evaluating the quality and progress of the CATTS program but were also the most difficult to evaluate quantitatively. In this study, we report only on our qualitative use of the journals although we have begun to quantitatively document stages of partnership development and the evolution of the Fellows as teachers using the journals of three Fellows chosen randomly.

The journals serve several purposes. First, they provide a mechanism for the Fellows to reflect on their experiences in the program. Second, they serve as documentation of the activities and growth of a Fellow during the fellowship. We worked hard to build the trust of our Fellows so that they would communicate their triumphs, failures, dreams, and fears. The journals have been an incredible source of information on how the Fellows changed over time. Finally, they provide vital feedback to the program director and the program coordinator (the authors of this paper) on how to improve the program.

We required Fellows to keep journals throughout their semester-long training and during the year they were working in the schools. The journals were submitted monthly for feedback. We frequently assigned topics to stimulate the Fellows' thoughts for writing. The assigned writing topic was sometimes related to the Fellows' activities in the preparation workshop activities, which provided feedback to us on their understanding and comfort with different concepts and teaching techniques presented. We used this feedback to modify the workshop while it was in progress and in later semesters. When the Fellows were working in the K-12 classrooms, we occasionally asked them to reflect on a particular question. For example, we asked them to write their goals for the year and then months later asked them to reflect on progress towards those goals. We also asked them to reflect on their role as scientists in partnerships with schools.

Journal writings were pivotal in tipping us off to obstacles the Fellows faced when initiating a

partnership. We learned of their high expectations and related frustrations at not being able to contribute immediately to the classroom teaching; we also learned of the difficulties the Fellows had in defining their role in the classroom. As a result, we had the Fellows talk to one another about their successes and failures in small groups during the fall seminar class. This bolstered their confidence and provided the ideas and assistance they needed to communicate more effectively with the classroom teacher. Communication was the biggest problem identified through journal writings, and once the Fellows realized they had to communicate more effectively with the teachers, most problems were quickly resolved. As a result of this experience, we changed the way we conduct our preparation workshop to provide more opportunities for the Fellows to talk with their partner teacher before they begin to work in the school.

In the free-form writing that occurs in the journals, we find evidence of the impact Fellows have had on their teacher partners and visa versa. For example, one Fellow who was helping several teachers develop a new biotechnology curriculum had this reflection on her teacher partners.

In looking over my February journal entries I noticed that both Mr. J and Ms. K are both so bogged down in worrying about meeting deadlines that they don't see the great strides the students have made over the last 6 months. I have had the wonderful opportunity of sharing my perspective on student performance with them and that I see great and wonderful things happening. Ultimately I feel my biggest contribution this month to Mr. J and Ms. K has been to help them step back from the everyday action of the classroom and reflect on how far their students have come.

In another instance, a Fellow expressed concerns about a middle school teacher who was reluctant to use inquiry in the classroom. The Fellow then described her plan of action to teach the next chapter using skills developed in CATTS. Her plan shows real development of the Fellow as an inquiry-based teacher.

Currently, the students work independently and at their own pace but must complete a chapter in 3 days. Mr. T's usual response to a student's question is, "Did you read the book? The answer is right in the book! I am not going to help until you read! He then lectures the entire class about how they have to read the book.

I am going to present the next physics chapter in a different manner. I am not going to use the book as the only source of knowledge. Rather, I will use the demonstrations in the book and turn them into inquiry-based experiments. I am going to break down the chapter into the main

concepts and then have each student complete a set of investigations for each concept. Instead of lengthy directions, I will give them a simple goal (e.g., - See if you can balance 4 sinkers on this side and 2 on the other side) and a certain time to do it. Then we will discuss everyone's results as a class and talk about the key concept (e.g., You can balance 4 sinkers against 2 because when they are put at different distances it equals the same amount of torque on both sides...). Once everyone understands - we will move on. I'll let you know how it goes!

We also observed significant advances in the Fellows' maturity and confidence over the course of our program, but these are more difficult to qualitatively document. One advisor commented favorably about his third-year Ph.D. student who had been in the CATTs program while he was away on sabbatical for a year. He wrote, "She has become a more confident, mature woman. It has become clear to me the great benefits that she has received from this program." Another undergraduate Fellow told us he is now a better student as a result of his fellowship. He no longer sits in class quietly, wondering about something the teacher has said, or daydreaming. He now asks more questions when he is confused or curious. He realizes the importance of the student/teacher interaction in the learning process.

## **PEDAGOGICAL KNOWLEDGE OF THE FELLOWS**

Research shows that knowing the language and culture of the K-12 environment gives the potential partner more credibility and is important for developing partnerships with teachers (Sussman, 1993; Gomez, 1990). Assisting in schools also requires an understanding of the nature of good teaching and how students learn. We found that our teacher partners were often surprised, yet pleased, to learn that the Fellows were learning about common educational theories and practices in the spring semester preparation workshop. As one elementary school principal put it, "At first I thought this might be another "feel good" program but when I received word [from the teachers] that the science standards were being incorporated into the lessons that the Fellows were creating, I was sold on the project."

To measure the impact of the preparation workshop and Fellows' readiness to work in schools, we gathered data on their knowledge of issues related to K-12 education, teaching and assessment methods, national science standards, classroom management and other topics using a pre- and a post-knowledge survey. The survey contains a list of 35 commonly used words or phrases that describe educational practices or that relate directly to K-12 education. The assessment included items related to the creation of rubrics, the National Science Education Standards (NSES) (NRC, 1996), Maslow's Hierarchy of Needs and Blooms Taxonomy of Cognition, to name a few. This knowledge survey asks the Fellows to report, using a four division Likert-scale,

how well they know a topic. Response choices range from being 'Unaware' to having 'Little Knowledge', 'Average Knowledge' or 'Extensive Knowledge' of a topic (Table 2). The pre-survey was given during the first week of the spring semester workshop and the post-survey was given in May during the last week of the semester.

In year one, 76% of the students were unaware or had little knowledge of the 35 topics at the beginning of the spring semester workshop. In contrast, by the end of the semester, 76% reported that they had average to extensive knowledge of these same topics. Several topics on the survey were only briefly discussed during the workshop (e.g., TIMSS, habits of mind (from NSES), and metacognition). The students showed much smaller gains in their knowledge of these topics suggesting that the instrument and self-reported data are reliable. For example, in the pretest 96% of the Fellows were unaware of TIMSS (Third International Mathematics and Science Study). In the post-test, 48% were still unaware of TIMSS.

In the second year, we changed the preparation workshop based on what was learned from the Fellows' journals and workshop evaluations gathered in our first year. We focused less on the broad topics in educational theory covered in the survey and more on developing practical skills for the classroom such as questioning techniques and cooperative learning. This change is reflected in the survey data from Fellows entering during our second year. Again, 76% of beginning Fellows responded that they were unaware, or had little knowledge of most topics, but at the end of the semester only 53% had average to extensive knowledge of the topics (Table 2). The decrease in familiarity with the breadth of topics is likely due to the more focused nature of our workshop in the second year. In contrast, the Fellows' journal writings and our observations of the Fellow's in the classroom indicate that the Fellows were more successful in their classroom role. The Fellows expressed in their journals that the time spent doing inquiry in our preparation workshop combined with time observing in K-12 classrooms increased their confidence and understanding of their role in the classroom. Further, the Fellows seemed to establish partnerships with teachers more quickly and generally had a more significant role in the classroom sooner.

## **ATTITUDE SURVEYS**

A successful Fellow must have a positive attitude about schools and teachers in addition to knowledge of good educational practices. Most people's knowledge of K-12 education today is based on their own experiences, which are often out of date and too personal to be objective. Another source of information on K-12 education is the news; however much of the information in the news focuses on what is wrong in schools. Our concern in preparing CATTs Fellows to work with teachers was that they had a positive attitude about schools and teachers, and had sufficient knowledge of the culture and craft involved in K-12 teaching to be a contributor. To gather information, we developed a survey to measure the Fellows' attitudes about these

Topic	None	Little	Average	Extensive
Problem-based learning	-13	-30	15	28
Summative assessment	-77	-6	71	12
Theory of multiple intelligence	-39	2	21	16
National technology education standards	-40	-27	37	29
Scientific inquiry	-4	-26	-14	45
Pedagogy	-32	3	17	12
National science education standards	-36	-39	33	33
State science education standards	-36	-40	56	19
Lesson plan development	-9	-39	10	38
Methods of classroom management	-13	-35	17	31
Bloom's taxonomy of cognition	-61	5	31	25
Domains of learning	-57	0	37	19
Formative assessment	-81	-1	71	12
Maslow's hierarchy of needs	-52	7	8	37
Constructivism	-51	6	33	12
Addressing different learning styles	-17	-26	-11	55
Effective questioning techniques	-35	-30	17	49
Vertical integration of content	-55	36	13	6
Methods of student motivation	-35	-38	30	43
Grading rubrics	-46	3	34	9
Active learning	-22	-30	0	33
Scientific literacy	0	-27	11	16
TIMSS	-49	29	19	0
Learning cycle	-45	24	21	0
Cooperative learning	-35	-35	27	43
Performance standards	-39	-23	49	13
Horizontal integration of content	-63	38	18	7
Evaluation	-17	-33	24	27
Professional development	-17	-43	35.5	25
Metacognition	-49	8	35	6
Concept maps	-43	12	24	7
Habits of mind	-61	37	18	6
Wait time	-61	-12	24	49
Systemic change	-52	-25	46	31
Embedded assessment	-54	-3	33	24
Higher-order thinking skills	-35	-25	17	43
<b>Average Change (Pretest to Posttest)</b>	<b>-39</b>	<b>-11</b>	<b>26</b>	<b>24</b>

**Table 2: Percent Change in Educational Knowledge (Year 1)**

topics (Table 3). In addition, we wanted to document the Fellows' career goals and their feelings about teaching at the beginning of the program to determine whether these attitudes changed over time.

We surveyed the first- and second-year Fellows at the beginning of their spring semester preparation workshop, at the end of the workshop, as well as six months later. Table 3 shows the survey statements and the combined responses for Fellows participating in the first and second years for the surveys taken at the beginning and end of the preparation workshop. There was no statistically significant change in their attitudes documented in the survey six months later, so these data are not reported. The responses are provided in their original form (Definitely agree, Somewhat agree, Somewhat disagree, Definitely disagree) and as a summary of Agree and Disagree percentages for each statement. Using an odds calculator for ordinate data, we determined that no statistically significant change occurred in any of the Fellows' attitudes about teaching or careers over the period of the surveys for either the first year cohort or second year cohort. Thus, we combined the data reports for both years in Table 3 but only show the end-of-semester survey data for the two groups.

The surveys reveal basic characteristics of the students who seek these fellowships. We found that the Fellows' attitudes overall were very constructive and positive towards teaching. This suggests that our recruitment and selection process for the CATTS program is effective in identifying suitable candidates for the fellowship. An overwhelming majority (73%) viewed teaching as an important part of their future career and 97% believe that it provides a nice balance to research. Statements exploring feelings about leadership suggest that most Fellows prefer to be the leader in group activities (84%). In contrast, the Fellows have mixed feelings about public speaking with only 51% preferring to be the spokesperson for their group. The Fellows enjoyed working with young children (87%) and most felt they related equally well to teenagers and young children.

The Fellows unanimously agreed that helping others learn was very satisfying. Similarly, 97% of Fellows said that the best teachers they had made them feel special. However, they were of mixed opinion if teachers were bad simply because they did not care (40% agreed). In our workshop we stressed that teaching is a craft that can be learned and mastered. We also stressed that good teaching begins with clear goals and proceeds through effective planning. 100% of the Fellows agreed with these statements. However, they were nearly equally divided about the statement that good teachers have natural talents that cannot be learned (46% agreed). Observing master teachers who appear to teach effortlessly can explain some of this confusion. Those teachers seem to have natural talents.

## EXIT SURVEYS AND INTERVIEWS

We conducted exit interviews of the first-year Fellows and will do so for the second year Fellows. We also asked

both the teacher partners and the Fellows to complete surveys about the impact of the partnership on a variety of teaching areas. Only teachers who worked with a Fellow for more than six weeks were surveyed. Teachers were asked about the Fellow's impact on classroom use of inquiry, curriculum, sustaining curriculum changes, K-12 students' knowledge and attitudes about science, and the Fellow's skills and preparation. The survey results are contained in Tables 4a and 4b. Results show that Fellows helped the teachers use more inquiry-based teaching and that the teachers feel that these changes will be sustained.

Teachers also report that the Fellows were adequately prepared for their work in the classroom, improved their skills over the year and had a positive influence on student learning and attitudes about science. One teacher told us all of her 3<sup>rd</sup> graders want to be scientists as a result of working with the CATTS Fellows. These are encouraging signs that the partnership is having the desired impact.

Fellows were asked a series of questions that paralleled those asked of their teacher partners. Overall, the Fellows believe they had an impact on teaching and learning in the classroom. Fellows also agreed that their teacher partners had made a permanent shift in their teaching that will be sustained. The Fellows believed they were well prepared for the classroom, and that they improved their teaching skills greatly over the year but still needed lots of improvement. Sometimes it is difficult for Fellows to evaluate the progress of their teaching skills. When reflecting on their progress, one Fellow commented that her department head now asks her to give tours to important out-of-town guests. Upon further reflection the Fellow commented that "maybe this is because my communication and explanation skills have greatly improved as a byproduct of my enhanced teaching skills."

In the exit interviews, we focused on several key areas for discussion. When asked about the best part of the yearlong fellowship, responses centered on the Fellows' personal growth through interactions with the teachers and students or on the joy of creating new ways for students to learn. For example, one Fellow wrote this about her experience as a Fellow.

I think designing the curriculum, testing it in class to see how it worked and fixing it was fun. Being able to create something and to see where students had problems or which parts they really liked – this I enjoyed the most.

Another Fellow told us,

Teaching is exhausting because I find that so much of it is nurturing... I feel like I give a lot of energy. However, when a student seems to start to understand something, or to open up his or her mind, I get a lot of energy back. Grading, encouraging, disciplining if need be, motivating, inspiring, listening and understanding, preparing and implementing lesson plans... whew! It's a pretty tall deal! I must say, I'm

Statement	Definitely Agree	Somewhat Agree	Somewhat Disagree	Definitely Disagree	Agree	Disagree
Teaching provides a nice balance to research	69	28	3	0	97	2
Teaching is the most important part of my career	19	54	27	0	73	27
I prefer a career in which I can do research full time	0	11	40	49	11	89
I am usually an organizer or leader of a project	27	57	13	3	84	16
I prefer to work in a group rather than be the organizer	14	27	46	13	41	59
Speaking in public is a major challenge for me	5	30	35	30	35	65
I generally do not like being the spokesperson for my group	14	35	32	19	49	51
I am comfortable speaking to a group of my peers	19	24	27	35	43	57
I enjoy working with young children	49	38	11	2	87	13
I relate better to teenagers than children	16	35	41	8	51	49
Helping others learn is very satisfying	95	5	0	0	100	0
Teachers use peer review/group projects to reduce their work	0	6	31	63	6	94
Homework would not be needed if teachers did a better job	2	0	30	68	2	98
Bad teachers generally don't care	10	30	46	14	40	60
The best teachers I had made me feel special	81	16	3	0	97	3
Teaching is a craft that can be learned and mastered	47	47	6	0	94	6
Good teachers have natural talents that cannot be learned	11	35	43	11	46	56
Effective teachers have clear goals	97	3	0	0	100	0
Planning is the most important component of teaching	78	22	0	0	100	0
A teacher's job is to motivate	46	43	11	0	89	11
Teachers have less control over students than a researcher has in an experiment	13	30	46	11	43	57
Getting students to do work is the biggest frustration with teaching	3	14	55	28	17	83
Teachers control who will learn and who will not	17	53	19	11	70	30
Teachers make an important contribution to society	100	0	0	0	100	0
The best part of teaching is having summers off	3	24	32	41	27	73

**Table 3: Fellow's Attitude Survey (Year 1 and 2)**

Statement	Definitely Agree	Somewhat Agree	Somewhat Disagree	Definitely Disagree	Total	Percent Agree	Percent Disagree
I am more comfortable teaching new science / technology concepts after working with a CATTS Fellow	11	7	1	0	19	95	5
My knowledge of teaching strategies has increased since working w/the Fellow	6	9	3	1	19	79	21
After collaborating w/the CATTS Fellow I feel more comfortable teaching w/inquiry	12	4	2	0	18	89	11
I now integrate science throughout my curriculum as a result of my collaboration w/a CATTS Fellow	3	13	1	0	17	94	6
I have increased the use of science/technology in my curriculum while working w/the Fellow	9	7	2	0	18	89	11
New science concepts are just as challenging for me to teach as before collaboration with a Fellow	1	4	9	5	19	26	74
My use of inquiry has not changed after working with a CATTS Fellow	1	3	7	8	19	21	79
My teaching strategies have not changed since working with a CATTS Fellow	0	5	11	3	19	26	74
I plan on using inquiry as a teaching strategy as I develop new lessons	16	2	0	0	18	100	0
I plan on using the curriculum changes my Fellow and I have implemented	11	6	1	0	18	94	6
I am still not comfortable using inquiry as a teaching strategy	0	0	2	17	19	0	100
It will be difficult to maintain curriculum changes without the Fellow	1	6	9	3	19	37	63
I do not see myself integrating inquiry into new curriculum	0	1	3	14	18	6	94
My students have a more positive attitude towards science and scientists	12	7	0	0	19	100	0
My students show an increased interest in learning science	10	8	1	0	19	95	5
More of my students now consider the field of science as a career possibility as a result of their work with the Fellow	5	11	1	0	17	94	6
Student learning was not impacted by the fellowship	0	0	2	17	19	0	100
My students have not demonstrated an increased awareness of the importance of science	0	2	6	11	19	10	90
The Fellow has had a positive impact on my students' learning	18	1	0	0	19	100	0
The Fellow has helped me increase my use of inquiry in teaching	11	6	2	0	19	90	10
I would recommend the CATTS program to a colleague	18	0	0	0	18	100	0
Mentoring a CATTS Fellow took too much time to make it worth my time and energy	0	2	4	13	19	10	90
The CATTS Fellow is more comfortable interacting w/students after working in my classroom	11	6	0	0	17	100	0
The Fellow has displayed an understanding of the skills needed for teaching science through inquiry	14	5	0	0	19	100	0
The Fellow's teaching skills have improved significantly during our collaboration	12	5	1	0	18	94	6
The Fellow's comfort level in the classroom has not changed during our collaboration	1	3	7	8	19	21	79
The CATTS Fellow needs more preparation before entering the classroom	1	3	5	10	19	21	79
The Fellow's teaching skills need to improve greatly	0	1	5	13	19	5	95

**Table 4. Teachers' Responses to Impact of CATTS on Students and Fellows**

coming away from this fellowship with a healthy respect for just how much it takes for a teacher to do his or her job well!

In course evaluations and in journal entries written in the first half of the fellowship, Fellows made many references to what they had learned in our preparation workshop and how they were applying it in the classroom. However, when we asked them in the exit interview, "To what degree did the workshop prepare you for this teaching experience", the majority of Fellows felt that the training had little impact on their knowledge of teaching as compared to the experience in the classroom. The richness of working with an experienced teacher on a daily basis where sharing of ideas was open and frequent had a much greater impact on their teaching skills, as was expected. These experiences strongly overshadowed the preparation workshop by the end of the fellowship. However, we believe that the workshop was an important introduction to the culture and craft of teaching, and an essential element in creating the partnership, even if by the end of the experience, this element had become transparent to the Fellows.

Most Fellows indicated at the beginning of the fellowship that they wanted to include teaching in their future career plans as scientists, mathematicians or engineers. In many cases, the Fellows revealed that this goal was based on little knowledge or experience. For many Fellows (including those who had been graduate teaching assistants) the yearlong classroom experience in CATTs greatly clarified their thoughts and desires to teach in their careers. In addition, the majority expressed that they now felt they had the skills to be an effective teacher. All Fellows expressed the sentiment that understanding and treating students as unique individuals made the experience more rewarding. Finally, all Fellows agreed that the experience had given them the skills to adapt quickly and be flexible in the dynamic classroom environment. Fellows marveled at the insight experienced teachers had into their students and the many methods they used for assessing student understanding. (Similarly, teachers were equally grateful for the new science content knowledge they gained through the partnership). Many of these insights are not new to experienced teachers but can take a new teacher some time to learn. Through the partnership, the Fellows received an accelerated education in teaching and learning.

The biggest obstacle to building effective partnerships was communication. Both teachers and Fellows often pointed to a particular conversation in which their partnership made a real break-through. We worked extensively to help Fellows in this area. Fellows often believe that they will be able to 'jump right in' when partnering with teachers. Initially, they did not appreciate the importance of discussing their expectations with the teachers and investigating the teacher's expectations. When asked what advice they would give to the next year's Fellows they emphasized the importance of communication with the teacher and the need for extensive planning before teaching a lesson.

## CONCLUSIONS

Through a multifaceted evaluation program we gained important feedback that allowed us to continually improve our program through small changes. The Fellows' journals provided monthly updates on the quality of our preparation program and kept us abreast of developments in the Fellows' knowledge and skills. Our knowledge surveys combined with classroom observations and teacher exit surveys show that the preparation workshop is an effective means for providing the Fellows with key skills and knowledge they need to initiate a successful partnership. Our attitude surveys indicate that we were successful in recruiting Fellows with positive attitudes towards education and careers in teaching. Exit interviews with the Fellows and surveys of the Fellows and teachers indicate that the partnerships we have created will have a lasting impact on K-12 teaching. These same sources suggest that our Fellows have a much deeper appreciation for their role in K-12 partnerships and are prepared to continue them during their career. Finally, classroom observations, Fellows' journal writings, and teacher surveys shows that our Fellows are skilled at using inquiry in the classroom and are well on their way to being successful educators.

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