Evaluation of the Teacher Professional Development Workshops for the Biological Sciences Initiative at the University of Colorado at Boulder

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Executive Summary

Project Overview and Evaluation Goals

Numerous opportunities for professional growth are offered to Colorado K-12 teachers through the Biological Sciences Initiative (BSI) at the University of Colorado at Boulder. Through funding from a grant from the Howard Hughes Medical Institute, teachers can apply for mini-grants for classroom equipment, sign up for the Science Squad to present an interactive science lesson in their classroom, and attend professional development workshops given by university faculty and educators. This study focuses on the teacher professional development (TPD) workshops and examines a sample of three workshops offered between July 2003 and November 2004, entitled *Scanning Life's Matrix*, *Blue Baby Syndrome*, and *What is Cancer?*

The evaluation questions that are addressed include:

- What are the outcomes of the TPD workshops for teachers and students, including effects on teacher knowledge, pedagogical practice, and attitudes, on their selection of both content and teaching and learning strategies in the classroom, and on student learning?
- How do these outcomes come about—both during the workshops themselves and through the processes by which teachers use or adapt the workshop methods and materials for their classrooms? How do teachers use the workshop methods and materials in their classrooms?
- What are the barriers to implementing materials and methods from the workshops?
- How can the workshops be improved to increase their effectiveness?

The evaluation design included both post-workshop surveys to measure the immediate outcomes and later interviews with participants to investigate the longer-term impacts. Teachers filled out surveys following each workshop with a common core set of questions. These surveys were analyzed and reported to BSI at the time of the workshop to provide immediate and formative feedback. The survey findings are also summarized in this report and used to supplement interview responses.

The interviews with teachers were conducted to investigate the longer-term effects of the workshops on teachers' attitudes and classroom practices. Teachers were interviewed several months after attending a workshop, to allow them time to implement the activities and materials in their own classrooms, if they so desired. The interviews focused on teachers' classroom use (or lack of use) of any activities or materials from the workshops—what they used, how they chose and prepared the materials, how students responded, and their future plans—but also discussed other benefits from attending the workshop and the setting in which they taught. We asked teachers why they attended the workshops and what advice they had to improve them.

We investigated these issues through the use of ethnographic interviews with 31 teachers who attended the three workshops. These minimally structured interviews promote the discovery and in-depth analysis of issues important to both the interviewees and the interviewers, as opposed to testing the hypotheses of researchers who have already narrowed the issues to a precise set. The interviews were transcribed, coded, and analyzed using methods detailed in the report.

Summary of Findings

Survey Data

Surveys showed that teachers' responses to all three workshops were extremely positive. When comparing the workshop to other non-BSI workshops, all of the survey participants rated the workshop they attended as "excellent" or "good" and nearly all of them described themselves as "likely" or "very likely" to use materials from the workshop in their teaching. This report makes some general comparisons in gains from the three workshops to investigate the differences and strengths of each. For example, the highest-rated gains for *Scanning Life's Matrix*, a content-focused workshop, are concerned with teacher knowledge, while for *Blue Baby Syndrome*, a workshop organized around a case study approach, the highest gains are related to developing new strategies for teaching the material.

Why Teachers Attend

Two main reasons emerged that explained teachers' motivations to sign up and attend one of these three professional development workshops: to gather hands-on activities to use in their classroom and to increase their own knowledge of the topic. Teachers expressed satisfaction in having both expectations met at the workshops. Indeed, all but two of the 31 teachers had used or planned to use the activities, technology or content from the workshops. One of the most-cited gains from the interviews was an increase in teacher knowledge. Although most teachers identified more than one motivation for attending, we did identify a contradiction between the goals of those teachers who attend purely out of interest in the topic or in gaining scientific knowledge and those who see the main purpose of these workshops as having a direct effect on the classroom and the students.

Classroom Implementation

Perhaps the most obvious outcome of any program of professional development for teachers is its subsequent appearance in the classroom—changes in content, pedagogy, or other classroom practices that are implemented by teachers in response to the program in which they participated. Implementation was thus a focus of the follow-up interviews.

One of the largest changes reported by our interviewees was the addition of new materials or activities into the classroom—all but two teachers had used or planned to use content from the workshop. Of the 31 teachers we interviewed, 22 used at least one hands-on activity, 21 used some sort of technology, and 22 presented the workshop content in some other way such as through lecture, discussion or reading materials. Most teachers used a combination of presentation styles for the material: only five teachers said they used something from only one of these categories, while ten said they used something from all three.

Teachers did not implement anything wholesale, but rather "adopted and adapted" what they experienced in the workshops. For some, adjusting the materials to their own classrooms seemed to be obvious and effortless, while others would have welcomed more opportunity to discuss adaptation with workshop presenters and swap ideas with colleagues. Nonetheless, the high rate of use makes it possible to argue that the conditions are established that enable real impact on science classrooms. Additionally, twenty-seven teachers (87%) stated that they were planning to use the information from the workshop again, indicating a lasting impact on classroom content.

The Process of Implementation

Many teachers attended the workshop because of their own pre-existing interest in the topic or a belief that it would appeal to their students. They seemed to attend with the established plan of filling their lesson plans with activities or information from the workshop, already knowing or assuming that the topic would be a part of their curriculum. Other teachers, however, became convinced upon attending a workshop and getting acquainted with the activities or content that it was important to teach a particular topic to their students or to expose them to certain scientific methods, and made room in their curriculum to incorporate the new material.

Teachers decided what to use from the workshops based on a number of factors including time constraints for both planning and teaching, the fit of the workshop material into the curriculum, its appropriateness to their students and the ease of use of the materials or methods. Twelve teachers said that class time constraints played a factor in deciding what to use from the workshop in their classes. The amount of class time available often depended on how well teachers felt the workshop materials fit into their school or district curriculum. If a topic was not in the standards or not typically taught in a certain course, teachers felt pressured to cover the "extra" material as quickly as possible.

In order to make workshop activities or materials more appropriate for the developmental level of their students, teachers made small adjustments to the workshop activities and found ways to tone down higher-level material. The content level of the TPD workshops was considered to be very high—nine teachers said that some of the material or activities were too difficult for their students, and four of those did not use certain information or activities that they deemed too difficult. Teachers also made decisions based on an activity's ease of use—if there was a monetary cost for supplies, extra preparation or set-up, it was more likely to be omitted.

Evidence of Effects on Students

Teachers observed various student behaviors to determine whether students understood the material and were interested in the topic, including the questions they asked (mentioned by 3 teachers), what they said during discussions (2 teachers), their written assignments (6 teachers) and how well they predicted results (5 teachers). Teachers believed that students were able to understand the material and were interested in the topics, especially when they were current and relevant to their lives.

Eleven teachers stated that students' positive response to the material was partly due to the currency of the topic. Discoveries that are happening now in science were relevant because students saw and heard about these discoveries in everyday life. Some teachers chose to use these workshop topics specifically because these topics could make a powerful and personal connection between science and students' lives. The lessons helped students take a scientific perspective and gain knowledge about a specific issue that affected their lives, such as genetic origins of disease, water quality, or cancer.

Teachers tended to use the information from the workshops with higher-level classes, believing that the material was too difficult for younger students or standard classes. Ten teachers used it with an AP-level class, and seven used it with an Honors class. A large number of teachers stated that their students already held a strong interest in science, especially those who were enrolled in the high-level or AP courses, so therefore it was not uncommon for them to be so engaged in the class material. It may be valuable to encourage teachers to use the material from

the workshop with students from a range of backgrounds and abilities, and not just to focus on the "high-end" students with these seemingly advanced or cutting-edge topics.

Influence on Pedagogy

In presenting the specific content from the workshop they attended, five teachers mentioned an increased hands-on emphasis, and another mentioned using inquiry. Significantly, half of the teachers we interviewed from the *Blue Baby* workshop said that they otherwise would not have presented the information in the form of a case study—demonstrating that the pedagogy of the workshop, when explicitly modeled and discussed, can have am impact on the pedagogy that teachers use themselves. However, it is important to note that the teachers interviewed did not report the use of hands-on activities and inquiry as a *new* approach to teaching, and therefore changes in overall teaching style were less evident.

The teachers who attended these workshops reported that they were already largely practicing teaching styles that are in line with the inquiry methods that BSI promotes: sixteen teachers stated that they typically used a lot of hands-on labs with their students, and four teachers that they based many of their lessons on inquiry. Although an explicit goal of the BSI workshop program is to promote the use of inquiry methods and hands-on teaching and learning strategies, most teachers hesitated to claim that a TPD workshop had significantly affected their overall teaching style. In order to have greater impact it may be necessary to offer other types of programs to attract novices and the "unconvinced," or to seek ways to gather a wider spectrum of participants in these workshops.

Other Impacts

Gains in teacher knowledge were not directly assessed, but it was one of the most frequently mentioned self-reported gains by the TPD workshop attendees. Nineteen of the 31 teachers commented that they, as participants, learned a lot of science content. Compared to other workshops, teachers thought that the workshops were at a particularly high level. While a few teachers had difficulties applying the high level of information to their students, most teachers appreciated the depth to which they were able to explore a topic, especially one that was current. They claimed that they learned a lot of science content and were able to stay up-to-date, confident and excited about their subject because of the workshops.

Another impact is the community and communication that the workshops stimulate for teachers. Attendees enjoy having access to university resources and learning from professors. Eleven participants reported that they shared the information with other teachers at their school. This often occurred within a tightly-knit department, where, for example, all the biology teachers co-planned and tried to teach the same curriculum. Encouraging such collegial sharing may be one way to fight against the isolation in teaching careers.

Using the Literature

In one of the final sections of the report, we compared the TPD workshops with two different models offered by the literature on professional development. In *Evaluating Professional Development* Thomas Guskey describes five critical levels of professional development evaluation. The findings from the BSI evaluation are included at each level. The interview and survey data show the BSI had positive outcomes at each level of evaluation, especially on participants' learning. The weakest level from the evaluation was organization support and change, which was not a main goal of this program. Next, we use a book by Susan Loucks-

Horsley and colleagues, *Designing Professional Development for Teachers of Science and Mathematics,* to investigate how these workshops met seven principles of effective professional development. Similarly, our findings show that the program was fairly successful at meeting the principles, particularly in regards to helping teachers develop knowledge and skills and being driven by a vision for the classroom. In the report, we suggest being more attentive to mirroring methods to be used by students and forming stronger links to the system.

Acknowledgments

We would first like to thank the teachers who took the time to reflect and share with us their experiences at the professional development workshops and in their classrooms.

As always, we thank the members of the Biological Sciences Initiative for their input and interest, and for having well-designed programs that make evaluations easy!

We would also like to thank Laura Creighton for her work in getting this project underway and everyone at Ethnography and Evaluation Research for their interest and contributions.

Table of Contents

Introduction

I. Project Overview

This report discusses the findings of an evaluation of the Teacher Professional Development (TPD) workshops offered by the Biological Sciences Initiative (BSI) at the University of Colorado at Boulder. The study was conducted by an independent evaluation team from Ethnography and Evaluation Research, also at CU Boulder. Both the program under study and the evaluation were funded by the BSI through a grant from the Howard Hughes Medical Institute.

The BSI offers numerous opportunities for professional growth to K-12 teachers, primarily in the Denver metro area and Front Range communities of Colorado. Teachers can apply for mini-grants for classroom equipment, sign up for the Science Squad to present an interactive science lesson in their classroom, and attend professional development workshops given by university faculty and educators. This report focuses on the teacher professional development (TPD) workshops and examines a sample of three workshops offered between July 2003 and November 2004, entitled *Scanning Life's Matrix*, *Blue Baby Syndrome*, and *What is Cancer?*

The description of the TPD workshops on the BSI website[1] states,

> Our workshops, which are usually held on Saturdays, emphasize hands-on, inquiry-based laboratory activities appropriate for the classroom. These workshops are designed to help teachers implement the National Science Education Standards. Workshops are available to teachers for little, if any, cost. Most workshops are held on the CU-Boulder campus. Recertification (CDE) credit is available to teachers who complete a classroom report on workshop activities they use with their students.

BSI offers some 8-10 workshops a year, on weekends and in the summer, with a maximum enrollment of 20 teachers per session. While BSI also offers longer-length "courses" for graduate-level credit in the summer, these were not included in this evaluation. Workshop descriptions posted on the website specify the targeted grade level (elementary, middle or high), but any K-12 teacher may sign up for any workshop. Credit toward recertification from the Colorado Department of Education is offered for all workshops, and graduate credit from the university is offered for many.

The workshops are offered with three different levels of emphasis, although they all incorporate some elements from each. The three levels, and their objectives, are:

1) *Basic*—to address and update scientific content relevant to the secondary classroom, and provide hands-on activities for teaching that content;
2) *Advances in Science*—to address more advanced scientific content, incorporate the latest research, and provide some hands-on activities;
3) *Inquiry*—to emphasize process of scientific inquiry, allowing teachers to experience the scientific process themselves with the ultimate goal of replicating that experience for their students, engaging them meaningfully in inquiry and the scientific process.

This report focuses on three workshops:

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[1] http://www.colorado.edu/Outreach/BSI/k12/workshops&courses.html

Scanning Life's Matrix—July, 2003

Advances in Science: In this two-day workshop, participants examined the human genome and cutting-edge developments in gene mapping and the use of microarray technology. The agenda included lectures by guest scientists, computer activities, and a lab tour.

Blue Baby Syndrome: A Case in Ecosystems Ecology and Human Health—March, 2004

Basic: This single-day workshop used the case-study approach to investigate the effects of excess environmental nitrogen on human health. Participants considered environmental contaminants, human health, and biogeochemical cycles as they analyzed documents and data for a fictional case of methanoglobinemia (blue baby syndrome), analyzed water and soil samples, and designed an engineering solution to the problem.

What is Cancer?—November, 2004

Advances in Science: This single-day workshop explored the nature of cancer, the many kinds of cancer, and the formation, structure, identification and diagnoses of tumors. The workshop featured a series of lectures from a researcher with expertise on cancer biology, and activities on tumor growth, cell division, microscopic comparison of normal and cancerous tissues, and gene expression in cancer.

Because of timing issues, no inquiry-focused workshops could be included in the evaluation. However, each of the evaluated workshops did include inquiry-based activities. The workshops were intended to share cutting-edge information to build teachers' knowledge of the area and to supply teachers with ideas and methods for presenting the information to their students in hands-on, technology-based, or inquiry-based lessons.

II. Evaluation Design

A. Goals of this Evaluation

At the outset of this study, it became clear that the BSI staff had substantial experience in developing and presenting TPD workshops. They also had gathered evidence from internal evaluations that was used not only to improve their programs, but also documented that they could design and deliver a program that is well-received by teachers. High demand for the workshops and a high return rate of participants in BSI programs indicates that teachers continue to find the workshops valuable. Thus, as in other recent studies conducted by E&ER of the BSI programs (Laursen, Liston, et al., 2004; Laursen, Thiry, et al., 2005), we focused on the longer-term outcomes of this program: While the programs are well-prepared and well-received, what is their real impact? What is the effectiveness of these programs in meeting the BSI goals of improving science education and increasing interest in science? We also sought to gather information to help the BSI staff determine whether resources are well spent on these programs, or whether resources should be reallocated to other activities.

The evaluation questions that are addressed include:

- What are the outcomes of the TPD workshops for teachers and students, including effects on teacher knowledge, pedagogical practice, and attitudes; on their selection of both content and teaching and learning strategies in the classroom; and on student learning? Do these outcomes vary with the type of workshop?
- How do these outcomes come about—both during the workshops themselves and through the processes by which teachers use or adapt the workshop methods and materials for their classrooms?
- What are the barriers to the use of concepts, materials, and methods from the workshops?
- How can the workshops be improved to increase their long-term effectiveness and lasting impact?

The evaluation design included both post-workshop surveys to measure the immediate outcomes and follow-up interviews with participants to investigate the longer-term impacts. Teachers filled out surveys following each workshop with a common core set of questions. These surveys were analyzed and reported to the BSI at the time of the workshop to provide immediate and formative feedback. We also sought to develop a standardized instrument that the BSI could use for all its workshops. The survey findings will also be used in this current report to supplement interview responses. The findings from these surveys also confirmed our initial supposition that the workshops were well-prepared and well-conducted.

The interviews with teachers were conducted to investigate the longer-term effects of the workshops on teachers' knowledge, attitudes, and classroom practices. These interviews were conducted several months after the workshops, to allow teachers time to implement the activities and materials in their own classrooms. The interviews focused on teachers' classroom use or lack of use of any activities or materials from the workshops, but also examined other benefits from attending the workshop, teachers' motivation to participate, the setting in which they taught, and their advice to the BSI about the workshops.

The choice of qualitative interview methods for this study is particularly suitable for investigating the nature and range of longer-term outcomes and the processes by which they arise. These minimally structured interviews promote the discovery and in-depth analysis of issues important to both the interviewees and the interviewers, as opposed to testing the hypotheses of researchers who have already narrowed the issues to a precise set.

B. Study Methods

1. Survey Methods

Survey questions were developed to focus on workshop goals identified by the BSI staff. The immediate post-workshop surveys were completed by nearly every attendee of all three workshops (N = 46). Consent forms for participation in the follow-up interviews, contact information, and some data about participants' time frame for any anticipated use of the workshop materials were gathered at the same time. The surveys asked teachers to indicate their level of agreement with a number of different statements about their gains in understanding of the science content, understanding of pedagogical methods such as inquiry, and ideas for assessment and making lessons hands-on and relevant to students. Similar questions asked teachers to rate their confidence in applying these gains to their classroom practice. (These statements are listed in Table 2 below, in Section IV where survey results are discussed.) The survey questions were constructed using a Likert scale from 1-5, with 5 indicating the strongest

level of agreement. Because the same core set of questions were used for all the workshops evaluated, we could compile the findings across the three workshops.

The survey also asked teachers to compare the workshop to their other professional development experiences and included open-ended questions on aspects of the workshop that were most effective and those that needed improvement. If the workshop facilitators wanted to learn something specific about their particular workshop, extra questions were added. For example, for *Blue Baby*, questions were added about the effectiveness of the case-study approach, and for *Scanning Life's Matrix*, questions were included to probe teachers' response to the DVD-based materials used. After each workshop, the surveys were analyzed and the findings compiled into separate reports that were given to the BSI following each workshop. This report summarizes those findings already presented.

2. Interview and Qualitative Analysis Methods

These methods of data collection and analysis are ethnographic, rooted in theoretical work and methodological traditions from sociology, anthropology and social psychology. Classically, qualitative studies such as ethnographies precede survey or experimental work, particularly where existing knowledge is limited, because such studies can uncover and explore issues that shape informants' thinking and actions, and estimate the relative significance of these issues. The ethnographer generates hypotheses for the experimentalist to test and questions for the survey investigator to ask. However, with the aid of computer programs to assist analysis of text data, ethnographers have also been able to disentangle patterns in much larger text data sets than was previously possible, and to report their findings using descriptive statistics. Although conditions for statistical significance are rarely met, the results from analysis of text data gathered by careful sampling and consistency in data coding can be very powerful.

The interviews were minimally structured so as to encourage interviewees to reveal their own perspectives instead of tailoring their input in response to categories introduced by researchers. The protocols were developed and continually refined in response to emergent issues, so that insights gained from early interviews could be explored further in subsequent interviews.

To preserve confidentiality and anonymity, the names of interviewees were known only to the interviewers, kept in a locked drawer, and replaced with coded labels on all documents and tapes. In reports of findings, no interviewee is identified. The study was approved by the Human Research Committee at the University of Colorado at Boulder.

Interviews were conducted by telephone, tape-recorded, and typically lasted 20-30 minutes. Interview tapes were transcribed *verbatim*. The transcripts were submitted to *N'Vivo,* computer software that allows for the multiple, overlapping, and nested coding of a large volume of text with a high degree of complexity. Each interview transcript was searched for information bearing on the research questions. Information is typically embedded in speakers' accounts of their experience rather than in abstract statements. Transcripts can be checked for internal consistency among opinions or explanations offered by informants, their descriptions of events, and the reflections and feelings these evoke.

Segments referencing issues of different type or perceived importance are tagged with code names. Codes are not preconceived, but empirical—each new code references a discrete idea not previously raised. Because answers to the same question may differ in character or cover different issues, codes are developed to describe the nature of the response given, not the

question asked. Interviewees also offer information in spontaneous comments, narratives, and illustrations. They often make several points in the same passage, each of which is separately coded.

Each coded file contributes to the data set of both coded observations and the defined codes that label them. Groups of codes that cluster around particular themes are assigned to domains (Spradley, 1980). This interconnected and branching set of codes and domains grows into a codebook that, at any moment, represents the state of analysis.

The clustered codes and domains and their relationships define themes of the qualitative analysis. In addition, the frequency of use of particular codes or domains can be counted for the sample or for important subsets (e.g. by workshop session). Together, these frequencies thus describe the relative weighting of issues in participants' collective report. In this report, we have reported these frequencies in terms of the number of individuals raising a particular topic, which includes those who discussed it briefly, at some length, or in multiple instances during the interview. Because of the nature of loosely structured interviews (as opposed to the uniformity of survey questions), these numbers do not represent a true quantitative measure of respondents' feedback. Questions are not asked in the same order or with the same wording in every interview; and some topics arise spontaneously and thus are not represented in every interview. Comments made by a single individual may be particularly insightful in explaining and relating comments made by others. Thus, the numbers should not be used to make statistical inferences, but are nonetheless useful in that they indicate the general magnitude of trends.

C. Study Sample

Surveys: Forty-eight participants attended the three workshops. Survey data were collected from all but two of these, for a total of 46 surveys. Because several participants attended more than one workshop, the survey sample represents 35 distinct individuals.

Interviews: We conducted 31 interviews with teachers who attended one of the three workshops (64% of all participants). An effort was made to interview new participants, but there was still overlap in the interview sample because some teachers attended more than one workshop. Four teachers were interviewed separately about two workshops each, for a total of 27 distinct individuals interviewed (77% of the different individuals participating in the three workshops). The table below shows the participant data and the survey and interview samples, broken out by workshop and by gender.

The sample was selected from among those who had signed the form consenting to be interviewed and audio-taped, for whom we had current and correct contact information, and who had the opportunity (whether they acted on it or not) to apply information from the workshop to their teaching within the time-frame when we were conducting interviews. (Some teachers did not teach any related curriculum within the time frame of this study). The ethnicity and gender distributions of our sample are largely reflective of the total group of attendees, in that Caucasians and women predominate, but the interview sample slightly over-samples men relative to their actual representation at the workshops. Because the numbers of non-Caucasian participants are small, we do not report them here, in order to preserve confidentiality.

Table 1: Participant and Sample Data for the Evaluated TPD Workshops

Workshop	Number of Participants	Number of Surveys	Number of Interviews	Women Inter-viewed	Men Inter-viewed
Scanning Life's Matrix	19	18	13 or 68%	8	5
Blue Baby Syndrome	10	9	6 or 60%	5	1
What is Cancer?	19	19	13 or 68%	9	3
Total number of participants	48	46	31 or 64%	22	9
Number of *different* individuals	35		27		

Teachers were interviewed up to a year after they attended the workshop to allow them time to use (if they so chose) the ideas or materials from the workshop in their classroom. Most teachers used the information within three months, and almost all had used it within six months. Due to the timing of the workshop relative to the sequence of their curriculum, however, there were a few teachers who waited nearly a year before presenting any workshop-related ideas to their students.

During the interview, teachers were asked about their motivation to attend the workshop and whether or not their expectations were met. They described what they used from the workshop and their decision process in choosing what to use. Teachers were asked about their experiences presenting the information, difficulties preparing or acquiring materials, students' reactions, and other aspects of their classroom implementation. They were also asked about other impacts of the workshops, such as changes in their teaching styles or curriculum, their own knowledge and professional gains, and whether or not they shared the workshop information with other teachers.

In this report, we will discuss the findings from the teacher interviews, drawing upon and linking to the survey data when appropriate, and we will place the workshop outcomes within frameworks offered by the literature on science teacher professional development.

Findings

In the remainder of the report, we discuss our findings. Most of the findings come from the teacher interviews, but we have integrated the findings from the surveys, primarily in the section on the workshop experience. We have organized the findings in a chronological manner, starting with teachers' decision to attend a workshop and then their workshop experience itself. The bulk of the report addresses the longer-term, post-workshop outcomes, focusing on classroom implementation but also including other outcomes. Throughout the report, we discuss the processes by which these outcomes are achieved, through both the workshop activities themselves and teachers' later processes of decision-making, classroom implementation or adaptation, and dissemination of their new ideas to other colleagues. We examine teachers' reports of their students' responses to the new materials, address whether these implementations

are likely to last, and place the workshops in the context of the literature on effective professional development for science teachers.

We will first discuss what motivates teachers to attend TPD workshops. This is revealing in showing what type of teachers are drawn to the workshops and the expectations they have upon attending.

III. Motivation: Why Teachers Attend

A first step in achieving effective professional development of teachers is to get them in the door for the course or workshop offered. As was the case with teachers interviewed for the Science Squad evaluation study, filling spaces does not seem to be a problem: BSI has developed a following among teachers for their long-lived and well-reputed offerings. In interviews with workshop participants, many teachers reported that they had attended a TPD workshop or used the Science Squad before and had had excellent experiences. Several among this loyal group of teachers would sign up for anything that BSI offered because they felt that BSI offered high-quality professional development opportunities. The teacher quoted below explained how she was motivated to attend a workshop based on positive reviews of past BSI activities.

> The BSI workshops have got a good reputation as being the most interesting and well-planned and informative and provide some of the best hands-on material for high school classes in the biological sciences.

Past positive experiences and reputation also identified attractive features, including the quality of staff, and logistics such as registration, credit, location, parking, and food. Alone, these do not make a successful program, but they can be barriers to teachers' participation if not managed well. Aside from these necessary but not sufficient features, two main reasons emerged that explain teachers' motivations to sign up and attend one of these three BSI professional development workshops: to increase their own knowledge of the topic (mentioned by 25 teachers of the 31 interviewed) and to get hands-on activities to use in their classroom (14 teachers).

Most teachers named more than one reason for attending, and their explanations varied depending on the workshop offered and its relevance to their courses. For example, if a teacher knew that she would be presenting a unit on cells or cancer in her class, she might sign up for the *Cancer* workshop to get ideas for an interesting way to present the information. However, that same teacher might decide to attend the *Scanning* workshop because of a personal interest in the topic, even if she did not have plans to use it in her classroom.

A. New Information and Knowledge

The opportunity to learn more about a particular topic was the most-cited reason for attending, mentioned by 80% of interviewees. This was often stated in conjunction with getting hands-on activities, but four teachers mentioned that they went for their own knowledge despite believing that they would not be able to use any activities in their class. One motivation for teachers to build their knowledge of a topic is to be better able to answer probing questions from students.

> I was just interested in understanding better about DNA, and the technology that people are using, so that I can just—for myself, as well as for being able to answer kids' questions, and explain to them exactly how it works.

> This was probably more a background knowledge thing than activities. Just 'cause I think the main focus of this course was more to give background knowledge to the teacher, so that when you get questions about things, you had a clue, which I think is crucial. Because if you don't—if you're always gonna go, "I don't know," you're losing credibility with the kids.
>
> I think it helps, 'cause you never know what kind of questions you're gonna get from the kids, too. If you're talking about genetics, they see something on TV or read something—I definitely would rather be able to field questions that are more current than my knowledge was before I took the class.

Teachers wanted background knowledge whether or not they would be able to use it directly in their classroom. However, a few teachers specifically wanted to learn content that they knew would help them teach. They wanted information because they felt that their knowledge was weak in a topic area or because they were teaching a new course.

> …We are doing more molecular biology in all of our classes, as opposed to systematic biology, and so I knew that that would be helpful. And plus, I just started, this year, this Introduction to Biotechnology class. I just needed more information.

Because of the high level of information presented, many teachers mentioned high gains in science content knowledge, which will be further discussed later in the report. For many teachers, the workshop topics were appealing because they offered information on current, "cutting-edge" science and research that was difficult for teachers to find elsewhere.

> I wanted the latest update on cancer research and thinking.
>
> Because I get up-to-date information. It keeps me current.

Despite the appeal of this state-of-the-art science content, however, teachers also reported a tension between their desire to learn this material and their ability to use it. Because teachers perceive that current information is not well incorporated into planned curriculums (such as Advanced Placement, AP) or covered in state-wide tests, it can be more difficult for teachers to justify spending class time on new content areas. This potential barrier will be discussed in further detail later in the report when we discuss teachers' choices about what to implement from the workshops. However, it may also be helpful, when current information is presented, to place it in the context of state and national standards, state assessment frameworks, and college-preparatory assessments. Teachers (and students) sometimes hold inaccurate beliefs about the content of such tests, and examples of assessment items from tests such as the AP, ACT, or CSAP may be useful in showing them when current information is in fact being used.[2]

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[2] In an evaluation study conducted by E&ER for the ChemConnections project, student interview data showed that students believed that the innovative, inquiry-based, college chemistry modules being evaluated were not teaching them "real chemistry" that would prepare them well for future chemistry courses or pre-professional exams such as the MCAT. In response, faculty showed students MCAT released items that asked students to analyze data, draw conclusions, and make inferences, much as the modules asked them to do. Students were surprised at the overlap of the tested skills with what they were learning, and their anxiety about their preparation was reduced. Some even came to believe that their own instructors had written the MCAT exam!

B. New Hands-on Activities for the Classroom

The second major motivation to participate in BSI workshops was the desire to gather more hands-on activities, inquiry strategies, and experiments surrounding the content area. When praising the BSI workshops, teachers frequently commented that they were easy to use in the classroom. Even teachers who reported they were motivated more by the opportunity to gain personal knowledge appreciated the usefulness of what they learned.

> Some of the other [non-BSI] courses you can take are so useless. I mean, you go there and it's a lot of information, but really is nothing you can bring back and actually use in the classroom, and most of the material you guys have, from lab activities to small activities to some of the video material and even a lot of the labs we've incorporated … they're all great 'cause you know they're all applicable and they don't take too long to run in the class and they're good!

It is important to note, however, that the teachers did not report the use of hands-on activities and inquiry as a new approach to teaching. Rather, the teachers who attend these workshops reported that they were already largely practicing teaching styles that are in line with the inquiry methods that BSI promotes. None of the teachers who were interviewed described their reason for attending as to enhance a particular pedagogical style, such as inquiry or lab-based science. This finding is similar to the reports from our interview sample of frequent users of the Science Squad, another BSI-sponsored program. Teachers who already used and valued hands-on science were the ones who were most eager to bring more of the same into the classroom. (Laursen, Liston, et al., 2004).

Thus, TPD workshop participants were motivated to attend by their desire to incorporate more labs and inquiry-activities to supplement what they were already doing. They commonly expressed the belief that hands-on activities appealed to students and made science fun. One teacher stated that, without the BSI workshops, her curriculum would be less stimulating to students.

> My curriculum would be very boring without BSI. They're great. In fact, I'm teaching DNA right now, and every single activity that I've done with the DNA, it's all [from] BSI, every single activity. And every single activity is amazing. It would be really boring if I didn't go to those workshops.

Teachers attended workshops that they thought would provide activities to fit into a particularly sparse unit.

> Actually, the reason I signed up for that one is, you know, teaching biogeochemical cycles is kinda boring, and I was looking for some kind of activities that would spark it up a little bit.

Teachers continued to sign up for the BSI workshops because they felt sure that they would get something that was well-tested, interesting, and designed so that they really could use it in their classes.

> You can bring back and actually use in the classroom, and most of the material …I mean, from lab activities to small activities to some of the video material and even a lot of the labs we've incorporated… like labs that were involved in a previous class, on adhesion and viruses and bacteria and simulations for those things, they're all great. 'Cause you

> know they're all applicable and they don't take too long to run in the class and they're good!
>
> My frustration with the other ones [i.e. non-BSI workshops] was you'd walk away maybe with one or two neat things you learned, but not a whole lot you could really *use*, and because I have a family, you know, my Saturdays are—like with everyone, your time is very valuable. And I don't mind spending the time, and I live [45 minutes away] and I drive all the way to Boulder, but you know what? It's just worth it. They're just… the first time I went, I was like in shock!

It is obvious from the quotations above that getting activities or information that will be readily applicable to the classroom is very important for many teachers. In addition, teachers perceive the emphasis on appropriate hands-on activities as particular to BSI.

> They need to know what value, extreme value, this program is, BSI. What they've offered in terms of science teaching, because there's nothing like it anywhere else. There's nothing like it offered through other institutions, there is nothing that's scaled specifically to improving educational delivery of science concepts, particularly biological concepts, that comes close to what they do. It's the best thing that teachers have…. In terms of intensity of the subject material, ease of delivery, activity-oriented, taking concepts and turning them into activities that kids can understand—nobody else does that.
>
> …I don't do any other activities from anywhere else, because they don't really give activities at other places that you can use, and if they are, it's something that they've ordered from somewhere else, so they're just really boring. But the BSI, the activities are great, and I can say, "Yeah, they're actually doing this experiment at the University of Colorado right now, and this is based on that experiment," and the kids love them.

As the latter quotation indicates, the prestige of the university (e.g. for activities or labs presented that are based on university courses or research) may also contribute to the perceived quality of the activities and content provided.

C. Workshop Purpose: Knowledge or Application?

It is interesting to consider to what extent the motivations of the teachers reflect the goals of the workshop presenters, as well as the actual outcomes to be discussed in later sections. We identify some tension between the goals of those teachers who attend purely out of interest in the topic or in gaining scientific knowledge, and those who see the main purpose of these workshops as having a direct effect on the classroom or the students. Some teachers chose to attend despite knowing that they would not be able to use the information in their classes, including teachers who had retired.

> I went for my own learning so that I could have a better understanding … but with AP Bio, it's hard to incorporate that stuff.

Even if teachers did not foresee any immediate opportunities to use the information in their classrooms, they still might attend to see if there is anything that might be easy to incorporate, or if they thought there was a potential to use it in a later year.

> I did it to increase my own understanding, 'cause cancer's such a prevalent disease. …And also I'm teaching seventh grade science now, but I've taught high school in the

> past, and you never know. They're thinking of changing the curriculum in [my district] right now, so you never know when I might be able to use it.

The quotation below is from a teacher who has a strict and fairly inflexible curriculum that she felt she could not modify to include the BSI topics or activities. However, she continued to attend the workshops because they were interesting and she thought she might be able to find a way to use the information in an unofficial way.

> *Teacher:* Well, it used to be that they were interesting and that I could use them, but now they're just interesting. For my own personal information, and then I can just incorporate it "by mistake."
> *Interviewer:* Oh, sneak it in there.
> *Teacher:* When they're not watching.

Other teachers believed, however, that participants should only attend if they anticipated applying what they learned in their classes. They viewed the main goal of the TPD as impacting classroom practice and having a more direct affect on students instead of only teachers.

> I probably wouldn't take up a space in one of those classes if I didn't think I was gonna use it in the classroom, 'cause I know that's what it's for.

Especially when the workshops are so popular, the teacher quoted above would likely support giving priority to teachers who are currently teaching courses where they are able to use the material. These different beliefs about the purpose of the workshops raise interesting questions as to the goals of the TPD program: Are workshops viewed primarily as a means to affect teachers by adding to their background knowledge, pedagogical style, and excitement about science, or is the main point to reach students by improving their science classroom and exposing them to interesting science done in interesting ways?

The variety in teacher motivations to attend a workshop and in their expectations of what they think that they will get out of it might make it difficult for facilitators to plan or to please everybody. But most teachers expressed a great deal of satisfaction in having their expectations met. A few, though, were disappointed about not getting something that they were looking for. For example, they may have been seeking a more activity-heavy workshop rather than high-level information. A number of participants from the *Cancer* workshop commented on the lack of applicable classroom activities, stating that those presented were too simple or included materials that were difficult to find. So even though they were enthusiastic about learning a lot about cancer, there was still a note of disappointment in not being able to bring activities back for their students. These cases would occur even less frequently if more detailed descriptions were available on the focus and activity schedule of a workshop.

IV. The Workshop Experience: Summary of Survey Data

Once teachers have decided to attend a workshop, the quality of their experience is important in influencing the longer-term outcomes of their participation. Most of our information about the workshop experience itself comes from the immediate post-workshop surveys. This information includes teachers' rating of their gains from the experience, their expectations about using the workshop content, and their responses about which aspects of the workshop were effective or less effective. In this section we summarize survey responses from all three workshops. This data was already provided, in separate reports for each workshop, as formative feedback to the BSI.

The responses to all three workshops were extremely positive. When comparing the workshop to other non-BSI workshops, 38 out of 46 survey participants (83%) rated the workshop they attended as "excellent" and the remaining eight (17%) rated it as "good." Nearly all participants described themselves as "likely" or "very likely" to use materials from the workshop in their teaching.

The means for teacher gains statements (listed in Table 2 below) were all above 3.8 on a five-point scale. The highest- and lowest-rated gains for each workshop are presented in Table 2 below. The range in the gains ratings is too narrow, and the sample too small, to test for statistical significance, but some patterns in the survey data nonetheless reflect different emphases across the workshops. For example, the highest-rated gains for *Scanning* are concerned with teacher knowledge, while for *Blue Baby*, the highest gains are related to developing new strategies for teaching the material. The lowest gains for *Scanning* and *Cancer* are both about using inquiry methods. These differences are consistent with the workshop style and goals: both *Scanning* and *Cancer* were "advances in science" workshops, while *Blue Baby* emphasized case learning as a method for making science relevant and hands-on for students. Thus, even though all the gains are quite positive, it is possible to discern differences in the ratings that do reflect real differences in participants' experiences at the workshops.

Table 2: Highest- and Lowest-Mean Gains from Surveys, by Workshop.

Highest-mean gains are in **bold** and lowest-mean gains in plain font. Gains were rated on a 1-5 Likert scale, where 5 = "strongly agree" and 1 = "strongly disagree."

Survey statement	*Scanning*	*Blue Baby*	*Cancer*
1. The workshop enriched my understanding of the scientific topic.	**4.94**		
2. The workshop provided ideas for new strategies to assist my students in learning about the topic.		**5.0**	
3. The workshop contributed to my ability to use inquiry teaching strategies with my students	4.0		3.83
4. The workshop provided ideas to assist me in implementing district, state or national science standards.			
5. The workshop assisted me in providing ideas for hands-on activities appropriate to the content.		**4.89**	
6. The workshop gave me ideas to make the topic relevant to students' everyday lives.		**4.89**	
7. The workshop helped me keep pace with rapid advances in science.	**4.83**	4.44*	**4.95**

*In the survey as completed by participants, the facilitator adapted this statement to read as follows: The workshop exposed me to new science knowledge or techniques.

Overall, in returning to my classroom to teach, I am better able to:

	Scanning	*Blue Baby*	*Cancer*
8. Develop and teach a lesson or series of lessons on this topic for my students.		**4.89**	
9. Use a "hands-on" approach in teaching this topic			
10. Use an inquiry approach in teaching this topic	4.11		4.03
11. Integrate accurate scientific knowledge into my teaching of this topic			
12. Address student questions on this topic			**4.88**
13. Teach my students about some of the recent advances in scientific understanding on this topic, at a level appropriate to them		N/A**	
13b.** Use computers or other technology in the lessons	N/A	4.33	N/A
14. Capitalize on student interests relevant to the topic			**4.88**

**In the survey as completed by participants in the *Blue Baby* workshop, the facilitator omitted statement 13 and substituted statement 13b, which was not used in the other workshops.

Teachers' responses to the open-ended questions about which activities were most effective and which needed improvement give some insight into what aspects of the workshops made them effective. For all the workshops, teachers valued the gains in their own understanding of the topic—an area to which we will return in discussing the interview data. Experiential learning, including hands-on activities, experiments and tours, was mentioned as valuable in every workshop, both for building teachers' own understanding and as take-aways that they could use with students. Lectures or presentations by scientists that taught new concepts and helped teachers organize the material conceptually were generally well-received, although these also could be a problem spot—even an enthusiastic and engaging lecturer could sometimes go over participants' heads. Visuals, such as PowerPoint presentations, slides of cancer cells, and DVD animations, were mentioned as useful in visualizing concepts, but when more extensive computer-based explorations were used, teachers requested clear instructions and guidance on the structure and use of the computer materials. Teachers also appreciated receiving well-organized reference materials and resources that they could refer to, pass on to other teachers or re-use.

The workshop instructors were highly praised. Logistics and facilities were positively cited when mentioned at all, which was seldom. Several comments requested more time: better time management of a jam-packed agenda, and more time to ask questions, process information, and think collegially about applying it—for example, by brainstorming and sharing out of ideas for how to use or adapt workshop materials in the classroom. We shall return to this point again.

V. Workshop Outcomes: Classroom Implementation

Perhaps the most obvious outcome of any program of professional development for teachers is its subsequent appearance in the classroom—changes in content, pedagogy, or other classroom practices that are implemented by teachers in response to the program in which they participated.

Changes in teacher knowledge, professional behavior, and attitudes are also outcomes that can be documented (Guskey, 2000). We will discuss each of these types of outcomes, but will focus first on classroom implementation, which was the outcome of greatest interest to the BSI staff in our early conversations about the program evaluation. Likewise, the questions in the immediate post-workshop survey reflect an implementation focus, with objectives to increase teachers' knowledge, thereby enabling them to incorporate up-to-date science content in the classroom; to alter teachers' teaching and learning strategies, with particular emphasis on hands-on and inquiry learning; and to provide examples and activities that would engage students' interest in science and show science as relevant to students' lives. Teachers' discussion of the implementation focus (and the occasional tension they saw between this and simple improvement of teacher knowledge) shows that they too saw classroom implementation as a focus of the TPD workshops.

In this section, we discuss the workshops materials and methods that were implemented in the classroom and the circumstances in which they were used—the types of courses and extent of use. In the following sections, we discuss the process of implementation: teachers' decisions about what to use, the factors that influenced their decisions, their preparation for classroom use, and the barriers that they faced in implementing workshop materials. We then discuss students' response to the implementation, as reported by the teachers.

A. Materials and Methods Implemented

The rate of adoption of workshop materials and methods was impressively high. The surveys showed that a very high percentage of teachers predicted that they would use the information. And indeed, in the interviews, all but two teachers had used or planned to use something from the workshop in their classroom. One teacher could not use the *Blue Baby* activities that she had planned to use because of curriculum restrictions due to CSAP preparation, and another teacher was unable to work the *Cancer* information into an existing unit because it had already been taught and there was not enough time to add another. Both of the teachers who did not have the opportunity to use material from a workshop at the time of the interview hoped to use the information at a later time.

We have divided teachers' observations on their use of materials from any one workshop into three categories according to the teaching and learning strategies emphasized: hands-on activities, technology, and content. The category "hands-on activities" includes use of any of the more interactive labs and other types of activities (e.g. simulation or modeling); "technology" includes any lesson based on materials available through CD-ROM, PowerPoint, DVD or Internet media; and "content" is any idea, concept, or example that was brought up but used with a teaching method that did not fit in the other two categories, such as lecture, discussion, reading, or worksheets.

Of the 31 teachers we interviewed, 22 used at least one hands-on activity, 21 used some sort of technology, and 22 presented the workshop content in some other way. Most teachers used a combination of presentation styles for the material: only five teachers said they used something from only one category, while ten said they used something from all three. Again, these rates are impressively high, and might even lead to suspicions that teachers are giving the answer they think the evaluators "want" to hear. However, the concrete examples that teachers give in the quotations below support their statements.

1. Hands-on Activities

As previously discussed, many teachers relied on BSI workshops to get ideas for hands-on activities to use in their classroom. This was a large part of their motivation for attending a workshop.

> Actually, it's mostly the activities that I'm using to illustrate the content rather than just presenting content. So it's the activity-based nature of it that is attractive.

Teachers thought that making lessons more interactive helped their students become more interested and engaged and provided ways to visualize or conceptualize the material.

> And what we do is we make a model of the DNA, and it's actually a paper activity but… the kids love it, and my high-level kids have told me it really helps them to understand the concept of gene-to-protein synthesis.

Most of these teachers valued the role of hands-on activities to their classroom before going to the workshop, but had a difficult time creating their own activities to fit into a unit. Many were looking for interesting ways to fill the gaps in their curriculum (an aspect to be discussed more in detail, in the section on processes of implementation). One teacher, however, warned against overuse of hands-on labs in which the lesson could be overshadowed if students were just going through the motions.

> Sometimes the activities are so hands-on that they—I don't know if they really are a good mimic of what they would feel like in a living system. Like one of the ones where you're rearranging different regions on a string, with beads and different shapes and things, and identifying the different kinds of proteins you could produce. I'm not really sure the kids would even make that… they'd just think they were playing with beads… sometimes kids [don't] necessarily make that transfer from the model to the real-world situation that you're trying to describe. They get lost so much in the model that they don't really, you know, they don't see the connection.

Comments such as this may also suggest that the presenters may need to emphasize the scientific connections that students might make through modeling, and more broadly the way in which scientists use models.

Workshop attendees did not mindlessly use any hands-on activity that was presented. Rather, as we shall discuss in more detail below, they spent a good deal of time going over their options and deciding what fit best with their students, the curriculum, time frame, and other setting-dependent factors. It is evident, then, that not only was the quality of the hands-on activities important to teachers, but the quantity and variety of such activities available to choose from was also of value. In this respect, the BSI facilitators act as a "filter"—by looking for and evaluating existing activities (or, where none exist, developing their own), they both spend the time to do this that teachers do not have, and provide quality control for the activities they select.

2. Technology

Teachers expected the TPD workshops to provide up-to-date information. This included the use of technological resources in teaching. Schools are not able to afford fancy science equipment, such as high-powered microscopes or machines to analyze DNA. But teachers enjoyed being able to experience and use the equipment at the workshop, sometimes to become more familiar

with options available for classroom but often only to increase their knowledge and excitement about science.

Most teachers did, however, have access to DVD players, computers, and the internet in their classrooms, and the TPD workshops often used these as teaching tools. These are cheap and easy ways to bring in visual images and show different processes through animation that might otherwise be difficult to picture. Teachers had found these resources to help students develop concepts and to particularly assist visual learners.

> They really enjoyed the computer sites that I've taken them to, kind of just wandering through some of the information, and then doing some of the interactive activities they've enjoyed. A lot of the simulations help a lot too, I think, with them understanding some concepts.
>
> [My class is] mixed with special-ed and ESL students. So [there are] varied levels of learning. The visual part [of the DVD] was very, very important.
>
> …there's an animation on the HHMI Bio Interactive, and it shows the development of a tumor, shows the different stages of cancer, and how it metastasizes. It shows the development of a tumor and then the tumor becoming bigger and then the cells migrating to the blood stream and then going off and starting other tumors in other areas. They showed it to us in the workshop.

While the technology-based materials were useful to many, the technological requirements also posed some barriers to use. Four teachers did not have a DVD player or computer easily available, so were not able to use any of the technology-based lessons. A couple of teachers also reported trouble using some of the technology-based lessons. Web sites or links were outdated or a program did not work.

> I tried to get the doubling activity and it wouldn't download… It's *Mitosis Out of Control* with cancer cells. And it didn't work with the link…. It was suppose to work, and it was cool in the workshop. And the kids were actually supposed to sort of graph it, the information, and how many—count and kind of freeze-frame, and use that information as an activity, but that did not work. And I didn't try that with them. I tried it first and it didn't work.

Another common complaint was the length of the video lectures, especially the one from *Scanning Life*'s *Matrix*.

> And even though Dr. Lander is very entertaining, for ninth- and tenth-grade students it was just another lecture…. They have wonderful ways of describing things. It's just a matter of the fact that sometimes they don't like to listen to some of these speakers all the time.

Some teachers who recognized this problem with the style of the DVD materials took pains to customize the materials to adjust to their students' learning needs.

> The video stuff from the CD-ROM, some of the kids really, really enjoy it and they even like the lecture format on the video where they go through and they have the question-answer sessions. And some kids kind of get turned off cause it's just more of the theme, it's more talking—lecture-based, just on a video. But the speakers are good and then they have lots of little films or animations that help demonstrate what they're talking about….

> I go through and I try to break it up into small sections and actually save small sections of video clips and then incorporate those in along with the lectures. I think it would be hard for students to really sit there and watch one full presentation. Because it isn't really like a movie-movie, it's more like a lecture going on. It's not really interactive for them, they're just kind of watching the interaction, and so by breaking it up, it works out really well.

Thus, although we have categorized these uses of the workshop materials as "technology-based," their actual use of these materials shows that these teachers value the hands-on (or minds-on) aspect more than the technology *per se*. The technology-based materials were seen as yet another strategy for engaging students. Thus, having a diverse set of activities available at the workshop for those who are able to use them may again be the best approach, and the BSI staff's "filtering" work to select high-quality materials is an important enhancement.

The teachers' feedback might also be provided to those at HHMI who produce these materials, about how to better optimize the delivery of the materials for classroom use—some of which may be as much repackaging (e.g. "chunking" DVD material in smaller, more convenient units) as any real adjustment of the content. Finally, even if teachers do not use the technology-based materials in their classroom, this does not mean these materials are not valuable. For example, one teacher said that he watched the video himself to understand and visualize the content better.

3. Content

In addition to the direct use of the activities and technological tools that they experienced in the workshops, teachers incorporated the content in other ways. Even if they did not take class time to show a video or to set up a lab, most teachers presented the content that they learned in the workshop in another way, such as using the material in a lecture.

> Then I used a lot of the facts and stuff. I had just finished the unit on the cell, so I couldn't really use any of the activities. But I used a lot of the lecture material… and just a lot of the cool facts and stuff. Actually, we were already into the next unit, but I was too excited, so I just wanted to go back.

Especially with the *Cancer* material, which was viewed as a very pertinent topic, teachers were comfortable with starting a class discussion.

> I just used the information on cancer because I have a lot of kids who are not only curious about cancer, but have relatives or somebody that has it. It's a really big interest topic. It's mostly answering questions somewhere, talking about cell replication, and so forth. I mean, it just comes up all the time. So, giving me information to answer their questions is really good.

This approach raises concerns that students will become bored if a teacher is just presenting the information to them, but one teacher expressed her hope that at least some of the students would get excited about what they are hearing.

> Talking about cancer or genetics, like the microarray stuff, just 'cause that's where biology is headed. I think at this point probably 90% of the students, you spend a minute and describe the microarray stuff, and it goes in one ear, out the other. But for a few of them, you know, they're gonna be like, "Wow… that's really cool."

At other times, teachers used content from the workshop and embedded it in a different kind of activity, such as a graphing exercise or a research project. As we shall discuss below, adapting the material to their own students was a concern for teachers, and this was one way in which teachers modified what they learned at the workshop to make it appropriate for their classes. By providing them with the background knowledge, the workshops allowed teachers to be creative in how they chose to present the material to their students.

> I did the cancer piece using mitosis and uncontrolled growth and what happens there. So that was just a chart that I used with them, some charts I have on cancer growth and some overhead slides I have on cancer versus healthy cells and age of onset of cancer. That was graphing I had them do and some comparison of how we die in developing versus developed countries and we got to, "Now why is that? Why do we die of cancer here?"
>
> I take all the biogeochemical cycles and I made puzzle pieces out of 'em, and they're all mixed together and they cut 'em out and then by matching up lines, different lines and stuff, they reorganize it into each of the cycles.
>
> I used a lot of the interesting kind of side issues like, "Brain cancer usually starts somewhere else" [in the body]. And they did a project on some of the new treatments, new stuff in cancer research.

Finally, the other way teachers shared information in the classroom is by having their students read about a topic. For example, the *Blue Baby* materials included some magazine articles, and at least half of the teachers interviewed from that workshop had their students read the articles, either as a homework assignment or aloud in class.

B. Circumstances of Implementation

We have established that a high fraction of participants implemented some aspect of the workshop in their teaching, and the types of materials that they used. We will now take a brief look at the circumstances of implementation: the courses into which teachers integrated the workshop materials and the extent of their use of the workshop materials.

Many teachers (14) used the material within three months, while the information was still fresh. Seven teachers used it between four to six months after attending the workshop, and others waited longer, depending on their curriculum schedule and the unit into which they could best fit the new material.

Teachers usually spent a couple days of class time covering the material from the workshop. Four teachers used it for only one day, but fourteen used it for two to three days. It is difficult to further specify the amount of time that teachers spent covering material from the workshop because their schedules are so different (due e.g. to block scheduling), and many teachers stated that they worked the material in intermittently.

Nine teachers (29%) were able to use the material in more than one course. General biology was the most prevalent course, discussed by twenty teachers. Others included courses on biotechnology, anatomy, genetics, chemistry, integrated science, and others. It was frequently used in advanced courses: ten teachers used it with an AP-level class, and seven used it with an Honors class.

Two classes were very small, with less than ten students, and five others had between 11 and 20. Most classes, though, had a more typical number of 25-30 students enrolled.

VI. The Process of Classroom Implementation

We have established that a high percentage—nearly all—of teachers who participated in these three workshops did use some of the activities, materials, or concepts in their classroom teaching within the months following the workshop. A variety of courses, at beginning and advanced levels, were affected. We now discuss the processes that took place as teachers made decisions about implementing workshop materials in their classes and prepared to do so. This gives insight into the ways that workshop design does or does not support implementation, and into the factors that influence teachers' choices.

A. Deciding to Implement: Choices and Constraints

Many issues came into play after teachers have attended a workshop and were choosing which (if any) activities, information and technology to use with their students. Only one of the teachers decided to incorporate every single activity or idea from a workshop into their classroom, a teacher who used the entire case-study from *Blue Baby*. Most teachers viewed each activity separately as an option and chose what best fit their time, curriculum and students' interest.

> I've done a number of the workshops and I go into them with an empty head, without preconceptions of where it's gonna go. And I kind of look at it as a cafeteria, I pick and choose the things that I can use or that I can share with colleagues that I know they're doing similar stuff in their courses, so I can feed it to them. Or I can take bits and pieces and put them together into something that's, you know—expand the things we're doing.

One of the largest concerns of teachers was the amount of time they had available to allocate to a particular topic or activity. The amount of available time often depended on how well it fit into the curriculum of their school or district. Additionally, teachers chose material that they felt would be interesting to the students, at an appropriate level, and easy to implement. We now detail these factors in teachers' decision-making process about implementation.

1. Constraints of Class Time

Twelve teachers said that time constraints played a factor in deciding what to use from the workshop in their classes. There were multiple circumstances in which time influenced what was chosen. At times a teacher did not have room in his or her own planning schedule to work on finding materials and setting up a new lab. If an activity or video required too much class time, many teachers reported they were not able to use it.

> There was the whole thing with looking at the leukemia, and the two different types of leukemia with the microarray, but, again, given the time constraints that we only had three weeks for genetics, we just didn't have time to get into that level of detail. I think that would be better suited to a senior course where you have a little more time to focus, if the whole course is on, or you spend a whole quarter on genetics or something, and then you're getting the kids that are like, "Wow, this is cool."

In some cases, the amount of time teachers allocated to a certain unit or activity was under their own control. They could make the decision about which topics were most valuable to their students and to cut down on the less important topics. In other cases, apparently more common, teachers were dictated by some time constraints from an outside source, such as a pacing schedule from the district or school.

> How I decided is, like I said, we had already finished the unit, and we're on a pretty strict time line 'cause we move kids at semester, and so we all have to be done with genetics. I hate that, for that to drive what I do, but you can only make up so many days when you fall behind. I can make up some, so the activity just wouldn't have fit.

Time constraints may have prevented teachers from the *Blue Baby Syndrome* workshop from using all of the activities together as a case study.

> It was too long and the kids thought it was interesting at first, but then it just went on too long. And it was a little too tedious after a while, so I would definitely shorten it to probably two days.

It may be valuable to offer multiple versions of a single activity, including ways to shorten the activity or make it less complicated, or to invite teachers to offer their suggestions.

2. Fit of the Material into the Curriculum

Time became even more pertinent if the workshop topic did not tie in strongly with the curriculum. If a topic was not in the standards or not typically taught in a certain course, teachers felt pressured to cover the "extra" material as quickly as possible. Again, teachers did not have complete control in deciding what to teach and for how long.

> I have to coordinate what I do on a day-to-day basis, or a unit basis, with a couple of different things. One is with other teachers and one is with district curriculum. And then there's state testing stuff, and so all of these things. Whenever I decide to do something, whether it stays or goes, or whether I emphasize it or just, you know, kind of mention it in passing, has to do with all these different factors interacting.

AP courses were reported to be even more restrictive, due to the pacing and amount of content that must be covered.

> Right now, this year, I have absolutely no time to try to do new stuff. AP Biology is not going to be able to handle—probably, until I get real comfortable with it—other activities.
>
> There were several [activities], I think, I wish I could've done, but it was just because of time and the pace in an AP class you can't do.
>
> …and what was relevant to our course outline and stuff. I mean, there was one student that was taking the AP exam, and you don't need to know it in that much depth for the AP exam.

Many teachers believed that the content level of the workshops might be best suited to their advanced students, but in those classes they also seemed to be under more pressure to teach a prescribed curriculum.

We have already noted that many teachers sign up for the workshops without necessarily needing or even wanting to use the material in their classes. One teacher was not teaching any course where the content was relevant.

> …because I wasn't teaching any… life sciences directly, I didn't use any of the activities. But I think, you know, if I was teaching biology or general science that has the genetics component, I would definitely use some of the hands-on activities.

Similarly, another teacher used only what related to physiology, since that was the course she was teaching.

Two teachers decided what to use based on what they were lacking within a particular unit. If there were weak areas where they did not have any activities or enough information, then they looked specifically for activities or materials to fit there and supplement the existing unit.

> Basically, I just used it to augment my geobiochemical cycles unit. And it just fit in perfect with things that I could do, because it gave me some readings the kids could do outside of class, which didn't use up my class time, which is always a big problem, because there's more to teach in biology and you can get caught. And then it gave me some hands-on activities that I was kind of lacking.

> …just where it fits in the flow of what I'm doing. I mean, I have some activities that I've already had in place, and so I guess I pulled the ones that I was weakest on, you know, the topics that I hadn't really touched much upon, because I didn't know a lot about them. So I just kinda pulled more of those, in terms of what I've added in.

3. Appropriateness of Material for Students

In choosing what to use from the workshop, teachers also considered the relevance or interest of the topic to their students and the level at which the material or activities was targeted.

> If I had a student that was just really fascinated by it, I would tend to use it more. These guys, well, I mean, they were learning the basic stuff, too, so they weren't ready for it.

> If I lived in farm country, I know that's a really huge issue there, but because it's a suburban school, I didn't see directly application to the students' lives. So I thought that the idea that the water in their environment might be contaminated with *E. coli* might be more of an interest to them, so I kind of ran with that activity that we did [in the workshop], kind of modified it.

Making science exciting and significant to their students was a main priority for many of these teachers, influencing not only what they chose from the workshop, but their overall curriculum. Although there may be some variation depending on the students' backgrounds, there was general agreement among teachers about what is relevant and interesting. They expressed the belief that keeping students active and involved is important. This was apparent in teachers' reports of their typical teaching style as well as in the decisions they made about what to use from the workshop.

> I guess just gut feeling about what appeals to students and motivates them. They generally are motivated by things, usually, where they're active, but they also like visual things. They don't particularly like you talking to them that much.

Besides trying to choose something to appeal to the students, teachers also had to take the developmental level of their students into consideration. Some teachers thought various activities were too simple for their students, while others had to work to make them easier.

> Some of it will be based on how skilled my class is. You know, sometimes you have a really high-falutin' class with a lot of really high-level kids who already know quite a bit, and I'd use it certainly with them. In other cases, I would maybe tone it down and use just small parts of it, for classes that were more average, I guess.

> …Well, some of the stuff was pretty basic. I mean, this is one where you just pick the stuff that would work for your level, and so I just picked the stuff that would work for an honors level because some of the stuff was too easy.

The changes that teachers made to the workshop materials and activities to adjust them to the level of their students are described later in the report, but these comments do elucidate an important issue. Such comments from teachers may reflect real differences in students' readiness and abilities, and teachers' sensitivity to that. They may reference real differences among concepts as to whether they are appropriate, too elementary, or too abstract for students at various developmental stages to grasp. However, comments like these may also reflect some misconceptions about student learning—and in particular, the degree to which even "bright" students need concrete examples, experiences, and models to develop concepts and lots of practice to master them (Bransford et al. 1999). A "simple" activity might be constructed in a more independent or open-ended way for advanced students, or used to engage interest or curiosity before tackling a harder example. In a modeling activity, students might be asked to explain the model themselves rather than being told what it models and how. Likewise, some "advanced" activities may be simplified or taught with a qualitative rather than quantitative emphasis.

Particularly since so many teachers are already using and adapting workshop materials, it may thus be important for the workshops to build in more explicit discussion of this issue of adapting activities to different student audiences. Facilitators might provide more context for the learning goals of the workshop activities by more clearly discussing their own choices of teaching and learning strategies within the activity, and by having teachers analyze both the science outcomes of the activity and the merits or demerits of the teaching approach it employs. Teachers might be provided more opportunity to brainstorm with colleagues about how to adapt particular materials or activities for different audiences.

4. Ease of Use

Overall, teachers expressed a high degree of satisfaction with the way the TPD workshops enabled them to find something that they could easily use in their classes. Many aspects made workshop material convenient to use, but some considerations arose, such as the monetary cost of implementation. Some activities from the workshops used slides, test strips, fish tanks, and other specific supplies that teachers had to acquire if they wanted to use that activity.

> …Whether or not I could actually pull it off without too many expenses or really going overboard on the workload in preparation.

> I'm a part-time teacher, and I don't have any budget really, so I can't really go out and buy stuff like that. Whereas if I was a real teacher—and I don't know if I'd wanna, you know, how much money I'd wanna spend on that kinda stuff—but it was a nice activity. I like that activity, but I couldn't really use it.

Teachers may need to be alerted more directly to the opportunity to apply to BSI for a mini-grant to acquire such equipment.

When time was also an issue, teachers wanted activities that required little set-up or preparation.

> I guess the things that I used were the things that were most easy to use, like the DVD, obviously very easy to use, 'cause you can pick which lecture you think is relevant, and you can also stop and start whenever you want and talk about it.

In summary, teachers made active decisions after attending a workshop about what among the workshop materials would work best in their classes. They considered the time involved and the fit of the material into their curriculum. Teachers also gauged students' potential interest and tried to make the lessons relevant and appropriate to their students' learning needs.

B. Preparing to Use the Workshop Material in Class

Once teachers made the choice of what from the workshop to apply to their classroom, they spent additional time reviewing the material they would teach and making adjustments to meet the level of their students.

1. Reviewing Materials

For some teachers, just practicing the activity and seeing its implementation in the workshop was sufficient to feel comfortable enough to teach it. Others, however, felt they needed to look back through their materials, such as the workshop notebook or any notes they took, to re-familiarize themselves with the ideas they planned to teach. This was especially true if there was a long gap between attending the workshop and using it in the classroom. Eleven teachers stated that they looked over the materials before they taught.

> I will always go ahead and review all my notes that I take myself and all the materials that they give us. And then at that point I just decide what portion of it I want to go ahead and present to the class.

This is often the time when they actually decide what to use. Two teachers stated that they did the entire experiment or activity themselves before using it with their students. That way, they could foresee any difficulties that might arise. Teachers took time to explore computer materials from the workshop, such as a CD-ROM, DVD, or web sites.

> *Teacher:* Some of the computer activities I'd like to try and incorporate in class too, but I just need to actually kind of go through them again and see how long they really would take with some kids and, you know, set it up and …see if it would actually go okay.
> *Interviewer:* So it sounds like you're still in the testing phases?
> *Teacher:* Yeah, it's a lot of trial and error, like for me it takes… you know, one year I'd add a couple things and the next year I'd add a couple more things, so I just keep on going through that way.

One reason that teachers reviewed was to prepare the lesson, and the other was to revisit the content for their own understanding. It became apparent in the interviews that teachers were always in the "testing phase." They continually modified their lessons based on their experiences in the classroom. We will have more to say about this trend later in the report.

2. Adjusting and Adapting the Materials to the Classroom

Eleven teachers (5 from *Blue Baby*, 6 from *Cancer*) stated that they did not have to make any adjustments to what they learned at the workshop before they used it in their own classrooms. However, nine teachers said that the material or activities were at too high a level for their students. In fact, four of those did not use certain information or activities because they were so difficult. The others just made an effort to tone down the depth of the content or to make the tasks easier. From *Scanning Life's Matrix,* teachers mentioned the DNA web sites, the bead activity, and the video as being too difficult.

> …Some of the activities I knew I had to revise a little bit. I mean, they're a little complicated and I don't know, maybe that's just from who's written them, but they aren't quite ready, I think, for high school, in terms of being concrete enough. So I've altered some things to sort of get them more in the sphere of where I think they'll work. I've gone, actually a lot, to the DNA interactive site, now that they've got that up and running, and pulled some of the activities off there which are related, similar to what some of the ones that were in class, but …actually the format's really good on a lot of those, so I've gone and used a bunch of those.
>
> *Teacher:* Well, I remember that bead thing that we did.
> *Interviewer:* And you used that in your class too?
> *Teacher:* A modified version. Yeah, kind of a scaled-down one.
> *Interviewer:* Why? Because of a time factor or understanding?
> *Teacher:* Yeah, in complexity. I mean, the way it was developed was really neat, but it would have taken from other things that I had to teach and so I had to scale it back to fit it into the big picture. But I thought what they were doing was really effective, you know, the idea that the BSI people put together.

Three teachers who had a large number of English Language Learners (ELL) almost always had to adjust the material in some way—either by adding more visual and kinesthetic aspects or just by focusing more on vocabulary.

> *Teacher:* Many of my students have only been in the country for two years and are learning English. I will probably need to simplify the vocabulary. I always put together my own set of notes, which I prepare for the kids. If there's any kind of worksheet, I always redo them.
> *Interviewer*: And you just change the vocab, make it more picture-oriented or…?
> *Teacher*: Both. Vocab, picture-oriented, cut down on the amount of information presented, try and pull out key points. They're average kids, and so at tenth grade they've had some background, often in biology, in their native countries, so yes, I have to abbreviate the assignments. I need to focus on the key concepts so they don't get lost in the words—but it's possible to show them where we're going.

Again, this might be a fruitful area for teachers to share implementation ideas or strategies that they have tried to adapt materials for use with their ELL students.

Teachers from the *Cancer* workshop especially thought that the content needed to be simplified for their students to understand.

> They had a whole thing, and then it would describe, it had a list of each cell and describing what was going on with each cell in terms of the symptoms of the cervical cancer, how you could tell the ramifications of it in the cell. And I would, instead of just having all one big picture and then a key, I'd probably separate it out so they would just have the one picture, just because it would be less confusing.
>
> With the cancer, I needed to, I still need to look at it and probably bring some of it down to the middle school level. I'll just take a look at what I have, and see how I can compare it, or you know, I don't know, drop it down a little bit. I think one of the labs with the yeast growing, tumor growth, and I was going to do that. And try to maybe modify it a little bit for the kids.

> There's some schools I suppose where you couldn't even present any of this stuff because the kids wouldn't be ready for that level of stuff, 'cause most of the stuff is pretty high level. But there's always something that can be used, I found, in some level.

One teacher discussed the differences among schools in terms of the science preparation and academic skills of their students. She felt it would be difficult, if not impossible, for BSI to find activities that would be appropriate for all of the classes represented among the teachers in any given workshop.

> … I'm teaching Earth science this year in middle school, and a teacher from [another] school, a high school teacher who is teaching honors-level Earth science, came into my class…. So she was visiting classes, and she sat in on my Earth science class, and we were preparing for a test, and after the class was over, she said that my grade eight Earth science students knew much more than her honors-level high school students in Earth science, in terms of the level that we were going and their understanding the concepts and their vocabulary and all that. So if you were gonna offer something in a Denver school, it'd have to be something that was very exciting and pretty basic in order to be worth using, because the kids are not—they're just not prepared in many ways, and it's not the teacher's fault.

Again, offering a variety of activities, as teachers reported they gained from the workshops, appears to be a good strategy to assure that all participants find something that they can apply to their own classroom. It might also be helpful to include suggestions for modifying one activity to reach different levels of students or to accommodate different time frames or learning goals, as well as to provide more opportunities for teachers to develop these ideas themselves and with colleagues. Adapting workshop materials to the classroom might be a fruitful area for follow-up sessions for individual workshops: for example, a follow-up workshop or "implementation fair" might offer a chance to reconnect with colleagues, share ideas and experiences, and work together in small groups on adapting materials to similar settings (e.g. middle school, AP courses, or ELL learners). This idea was offered by a few of the TPD participants. In addition, providing workshop handouts and materials in an electronic version (on a CD or through a password-accessible web site) would reduce the amount of work for teachers in adapting materials to different settings. Teachers might contribute their own, alternate versions of activities to such a web site and begin to build an archive of adapted materials.

VII. Barriers to Implementation

A salient point from this analysis so far is that teachers did not implement anything wholesale, but rather "adopted and adapted" what they experienced in the workshops. In doing so, they had already solved several different kinds of potential problems—of acquiring materials, adjusting the level of difficulty of concepts or vocabulary, or adapting the materials to their course, classroom setting, and students' interests and abilities.

In addition to the problems that they solved along the way (and may never have considered to be "problems"), we specifically asked every interviewee about the difficulties or barriers they faced in using the workshop materials in their own classrooms. Many individuals stated that they encountered no problems, or only very minor problems; but as a group, teachers did report various difficulties. These barriers largely mirror the factors that teachers reported to influence their choices about whether or not to implement workshop ideas (indeed, the congruity of these responses lends credence to both). Thus, factors that encouraged implementation or adaptation

were also those that could become barriers when unavailable or unsolved. Some of these are factors out of the BSI's immediate control, but it should still be helpful to know what barriers exist so that they may be creatively addressed, or at least explicitly acknowledged, as challenges teachers will face. Problems that the BSI planners may be able to address directly included difficulties in acquiring the specialized materials required for the activities and with information provided at too difficult a level to use with the students. The other problems reported, which may be more difficult to address directly, are barriers posed by curriculum limitations, by time restrictions, and by a lack of technological equipment. However, as shall be seen, some of these may be addressed by providing other information that addresses the beliefs that underlie the perceptions of problems.

A. Problems Acquiring Materials

Nine teachers mentioned problems acquiring materials, including everything from difficulty finding, buying, or making materials. Teachers from the *Cancer* workshop mentioned that they would have liked to show students the slides of cells that they saw at the workshop but did not know where to purchase them.

> They had some slides there of some different cancerous cells from like a pap smear, but they said that they weren't available to buy yet or something… 'Cause I think that would be a great lab. We were able to look at them, but they weren't available for us.

Time is always an issue for teachers, and when the preparation for a lab required shopping and spending money, it was not always worth it.

> We asked where they got them from, and she got it from some bead store in Boulder on Pearl Street. And that's not something I can do, I just don't have time. Things like that really need to be put together in a small kit that could be sent out or something like that.

A low cost of implementation was preferable, as those who could not afford to spend money on lab materials would choose not to use an expensive activity.

> …Using test strips, they get a little expensive. That's probably one of the drawbacks to it.

Other, more infrequent, problems included difficulties preparing or assembling the materials.

> I just had to make it like three different times, and it didn't work, and then the refrigerator was too cold, so it froze, and it was all messed up. But I tried, so it was just difficulty making agar… to make the cubes.

Several teachers suggested making a kit available with equipment that is too expensive or too difficult for every teacher to acquire their own. When they were planning to teach that unit, they would be willing to go check it out. Kits might also be available for sale. The kit could also be a way for teachers to try out a lab or activity before committing to purchase of equipment for it, or could aid in preparing a mini-grant proposal. At a minimum, materials lists with information about sources and costs should be made available, so that acquiring materials was straightforward if funds did become available.

B. Problems with the Level of Difficulty

We have already discussed the adjustments that teachers made to the activities from the workshop to make it more comprehensible to their students. At times, however, the level of

difficulty prevented teachers from using the information at all. Nine teachers talked about the complexity of the workshop material. The quotation below came from one teacher who did try to use workshop material with his students, but based on their reactions, judged that it was too difficult.

> *Interviewer:* How could you tell that it was too difficult for them?
> *Teacher:* Oh, just, you know, typical response of kids to tune out and, maybe, act a little frustrated or start talking to somebody else during the lectures. That, to me, indicates either the kid doesn't care, or… but sometimes that indicates to me that the kid doesn't understand what's going on, feels frustrated with it and so, therefore, starts to tune it out.

Four teachers avoided using the materials because they decided that the complexity or depth was out of their students' reach.

> Most information would be really hard for middle school kids to even grasp, you know. But if I were teaching the human body and cells, actually, I'm not sure… I think eighth grade does the cell, you can introduce a little bit of it, but I just don't really cover any… it's kind of a reach for me to get it into my curriculum.

> I thought that the levels that they spoke at [in the lecture video] might have been a little bit difficult for some of the younger high school kids or some of the low-performing kids. So, I think that might have aimed a little high for them.

The level of difficulty of the workshop content is an interesting issue because it is an aspect of the BSI workshops that teachers often praise. It contributes to the growth of their own knowledge base, and many are able to pare down most activities to make them appropriate to the background and developmental level of their students. One teacher spoke about how she believed it was best to challenge students by presenting information that made them struggle at least a little. As in the quotation above, teachers cited students' troubles in understanding this challenging material as a barrier. However, as we will see later, most teachers ultimately reported that their students did gain a good grasp of the workshop material that they used.

C. Difficulties of Fit within the Curriculum

Fourteen teachers mentioned different problems they had using the information from the workshop due to restrictions of their curriculum. For example, they felt limited in what they could teach because of the curricular requirements related to testing or standards, or simply because of an already-packed curriculum.

> It's so packed with stuff we have to teach due to all those content standards that we have, that probably, ideally, you'd wanna have a little more inquiry learning, but inquiry learning takes time, and we don't really have a lot of time.

This bind frustrated some teachers who were eager to use the workshop activities, but felt they were unable to do so because the specific topic was not listed on the standards, or because there was no room in their schedule. One teacher from *Scanning Life's Matrix* discussed her view that the standards are outdated and therefore did not include the cutting-edge information she wanted to teach.

> *Teacher:* To be frank, it's hard in Colorado. We're under the gun to meet certain educational standards because of CSAP and that has cut into my time a lot…. It's hard for me to drop parts of my curriculum to expand on others and use this material the way

> I'd like to.
> *Interviewer:* Right. So does this not fit into the standards that you have to cover very well?
> *Teacher:* You know, it doesn't, because the state standards are not, in my mind, do not reflect current biology. It's a couple years old. We're one year away from a science CSAP and we're all pretty pressured to try to anticipate and deliver what the test will be. And I'm pretty sure that new, emerging parts of biology will not be accurately reflected in that. Or [in] the plan we're given to teach.

In a prescribed curriculum such as that of AP classes, there is only so much time to get through the required topics. If something new is going to be added, then something else must be cut down. Teachers reported that it was a constant battle to decide what is more worthwhile.

> There's only so much time to do stuff in Advanced Placement, so every time you add something, you have to squeeze something else out. And so I kind of go back and evaluate what we did and things that necessarily weren't very useful and take those out and try to, add something additional to that.

> We have limited amount of time… The kids are working in my class every day pretty hard, so whenever I add something, that means something else is gonna be taken out.

> They're always trying to cut days out of instruction, and cancer isn't really part of our curriculum, but I try to add something once they have the foundation down. I try to add things that are relevant. And, you know, you always have to look at what you have to get rid [of], and this just kind of solidified for me that that's something that's not gonna go.

One participant taught a biology course where a common curriculum was determined by all the teachers who taught biology at her school.

> I think we could have used it more in our integrated classes than we did, and I don't think that the BSI people could have given me more tools. The issues were more with my colleagues and trying to get them to—you know, if you add a unit that means you better drop one too, or else you're gonna be overloading yourself. As the course has become built, over the past decade or more, now people have some ownership to some of the things that are in there, and to tell them that goes for one of my things, it's a personal thing or a political thing. I don't push it too hard. I just try to add the most intriguing or the most appropriate to what we're doing.

The lack of decision-making power that teachers report over their curriculum suggests that the BSI not only has to convince teachers that their workshops provide valuable lessons, but their colleagues and the larger school administration as well. Efforts to work with groups of teachers from particular schools or districts to shape their curricula may contribute most to the type of systemic reform that underlies the issues raised here.

In addition, explicit attention should be paid, in designing workshops, presenting them and providing context for activities, to the state standards and assessment frameworks for the upcoming (new) tenth-grade CSAP test. In the present environment, new content (or new emphases within broad content areas) must be clearly standards-based in order to succeed in being integrated into the school curriculum. Perhaps the most difficult aspect of this is not linking information to the standards, but in conveying to teachers what the standard is really about and in communicating how a particular cutting-edge example may still teach fundamental,

broad concepts of life science. Our experience with teacher professional development in other settings suggests that many teachers have mastery of individual concepts but do not have the "big picture" of the discipline that a scientist who has deeply engaged in the field has developed. Thus placing workshop content within such a framework is a powerful role for university-based outreach efforts such as BSI's that incorporate real science and that involve science-trained professionals in substantive ways.

Finally, some of these teachers' comments undoubtedly reflect real constraints imposed by institutions and beyond their control, but others may reflect misperceptions about the standards, the state CSAP tests, and the relative weighting of material within these. For example, concerns about the perceived "lack of time" for inquiry activities may be countered by the anticipated weight of 30% for Standard 1 (inquiry and the scientific process) on the CSAP for all grades (5th, 8th and 10th)—greater than that of all the life science benchmarks at approximately 20%. Thus inquiry activities that also incorporate life science standards may be framed as particularly efficient uses of class time, rather than the "time sinks" that they are often perceived to be.

D. Insufficient Class Time

Closely related to curriculum problems is the constant time crunch in which teachers find themselves. Thirteen teachers mentioned time as a limitation to the amount of workshop material that they can incorporate into their classroom. This was often stated very simply:

> I didn't really have much [difficulty], my biggest limitation was time.

Most often, it was raised in terms of time available for adding new topics or emphases to the curriculum.

> We had the units planned and were already paring them back, 'cause it was getting into a time crunch and I'd been hoping to insert this in there, and it just, this year, it didn't pan out.

> [I would like to] actually spend a day or so and do the stuff on cancer, which unfortunately, we had like less than three weeks to do all of genetics…. It was way too rushed, 'cause, for me… it's kind of where the most is happening in biology these days, in a lot of respects, and the most relevant, I think, to the direction of biology in a lot of ways. So I'd prefer to spend, you know, at least four or five weeks on the genetics and obviously the cancer relates to that.

For *Scanning Life's Matrix* and *Cancer*, the content was considered to be important and relevant enough to try to work in. The *Blue Baby Syndrome* materials, on the other hand, were deemed by some teachers as too specific or too far away from the curriculum to dedicate a lot of time.

> If you're going to teach something as specific as this, it needs to be short and sweet… you don't wanna spend too much time on methanoglobinemia.

This comment may reflect legitimate concerns, but may also reflect a misunderstanding of the emphasis of the case study—that it addressed more than just a single disease. In this workshop, a case study was used to engage students with specific examples of broad concepts, while simultaneously developing inquiry skills, but facilitators may need to point out more explicitly these broad goals and the several state benchmarks addressed by the case study.

In sum, and as discussed in Section VI as well as here, the amount of time involved for an activity, first for preparation and then for in-class time, often dictated what teachers chose to use from a workshop.

E. Inadequate Technology

Four teachers did not have adequate equipment readily available, so they were unable to have their students access the web sites, watch the PowerPoint presentations, or view the DVD-based lecture.

> We don't have DVD machines at [our district], or at least not at our high school. So we can't use a DVD—plus the CD-ROM I can't use.

One teacher had five computers in his classroom, but even with that many it was difficult to plan a whole lesson around them. So even when resources were available, there were still limitations on how they could be used.

> The technology is always an issue. Like I said, we got the disc, but then that's one disc, and if I have thirty kids, and they all need to be at a computer or even two kids at a computer, can I take that one disc and transfer the information from that one disc to all my thirty, fifteen or thirty computers?… We do have a projector that I can borrow, but even if I have the projector, it was the kind of an activity that the kids needed to be in front of their own computer screen, at least two of them, 'cause you were counting little dots, and there's no way on a projected screen that I think they could do that. They needed to time it, they needed to count. Even if projected, it wouldn't really work. You could do it as a demo in class, that way, but it surely would be much more rewarding and fun for them to all have their own, to be able to look at their own little computer screen and count them and time it. I think it would be much more effective. So technology is always usually an issue, at least [in my district].

Aside from computers, other scientific equipment was lacking that could have added to the lessons.

> Understanding the technology behind the microarray was important, 'cause that was the core of what was being described, but that's theory that I needed so that I could convey the information…. I couldn't very well have kids doing microarrays. I mean, that's kind of out of their range and we sure don't have the machinery for it.

The focus of concern of these teachers was not that BSI included technology-based activities that they could not use; rather, they were more disturbed by the lack of resources in their schools. Because there were other hands-on activities and content ideas in the workshop, all four teachers were still able to use something from the workshop in their classes.

Finally, despite these issues, eight different teachers said that they encountered no difficulties in using the information from the workshop.

> The course is very well presented and extremely well organized, so most of that stuff is available. I won't have to work too hard for it.

VIII. Evidence of Effects on Students

We have focused our discussion of workshop outcomes so far on implementation. Within just a few months, all but two of the teachers had implemented in their classrooms some activity, lab,

visualization tool, or concept learned from the workshop they attended. Sizable proportions of these had implemented more than one type of activity or in more than one course. They described their process of implementation, including factors that influenced their choices about what to use and factors that got in the way of using other materials. Teachers implemented a wide variety of activities at different levels and depths—there is little consistency in what was implemented or, likely, in how well it was done. Nonetheless, the high rate of use makes it possible to argue that the conditions are established that make possible real impact on science classrooms. The rich detail about how teachers chose material to implement makes it possible to further enhance this impact in the design and presentation of future workshops.

However, while lack of implementation in the classroom certainly prevents the possibility of any benefits to students, implementation of classroom changes certainly does not guarantee them. In order to establish whether there is indeed real impact on the quality of science education in these teachers' classrooms, we need to know the answers to two further questions: What is the evidence that these implementations have any effect on student learning or interest? And what is the evidence that these changes are lasting and permanent, not just single, experimental efforts that are abandoned after teachers' initial enthusiasm about the workshop has worn off? In this section we first discuss the evidence for student gains from the classroom changes that were reported. We then discuss the evidence of lasting impact on science classrooms.

Teachers reported positive responses from their students towards the material that was implemented from the workshop. However, their statements did not indicate that they had noticed any significant differences in response compared to their usual lessons.

> Oh, they liked it. I mean, the same as anything else (laughs). The students, they were not like, "Oh, good we get to learn more stuff!" But it went over, as well as anything hands-on. And new is exciting to them, things that they can link to the modern world.

The majority of the teachers interviewed described their teaching style as very similar to that used in the BSI workshops, so the students were not exposed to anything drastically different. Thus the intervention may be viewed as a relatively minor one—a lesson or two were affected, not an entire curriculum, and teaching methods were altered slightly but not dramatically.

Given this situation, both theoretical and practical considerations of the study design dissuaded us from attempting to measure student learning directly. The lack of homogeneity of the intervention (in both content and presentation) prevents use of a common instrument or assessment given to many students. And the difficulties of gaining permission to assess or interview students directly are prohibitive when weighed against the relatively small chances of measuring an effect from the small changes teachers reported implementing. Thus, we chose not to interview or otherwise evaluate the students' responses directly. However, since the teachers treated the first time they used the workshop material as a trial to see what worked best, they were very attentive to the students' responses, and we asked them to describe for us students' responses to the intervention in detail and to give examples. Thus we do have evidence about student gains from the workshop materials.

In order to better understand the student audience being reached, we asked teachers to describe the population of their school and the classes in which they used the workshop material. A few of the classrooms where workshop content was presented were very diverse. Four teachers indicated that their students were more than three-quarters minority students or English language learners. But most classrooms were much less diverse, with seven teachers stating that their

schools were comprised of mostly Caucasian students. Most teachers also described their students as high level or college-bound. The schools were mostly set in suburban or urban locales, with only one teacher describing her school as rural. Five of the teachers indicated that more girls than boys were enrolled in the class where they used the workshop material, and one teacher commented that this was typical for life science courses. It is apparent that, while we cannot characterize the overall student audience as highly diverse, we can state that a wide variety of students were exposed to the content or activities from the workshop. And, because of this diversity combined with the overall positive experiences reported, we can conclude that the material from the workshop was successful, in teachers' views, in reaching a wide range of students. However, reaching diverse student populations was not a strong outcome of this program as compared with other BSI programs that more directly target diverse or under-served students (Laursen, Liston, et al., 2004). We now characterize the types of student gains, and the evidence for them, that teachers reported observing in their classes.

A. Gains in Student Learning

As we have noted, many teachers implemented a new classroom activity, whether a hands-on activity, experiment, or computer- or multimedia-driven activity. An easy way to judge whether students have a good grasp of material presented this way is by their performance on the activity, such as coming up with quality predictions or explanations. In one class, while collecting data on water quality, students got some unexpected results and met the challenge of coming up with reasons to explain the trends. One teacher thought that her Honors and regular classes performed equally on the assignment, indicating that the activities were appropriate for students of multiple levels.

> I didn't see any difference between my Honors classes and my regular bio classes. I was watching in honors for the ahas and I just didn't get 'em. And that was kinda surprising to me because I thought, "Wow! Hmmm." Kids in this kind of activity, it doesn't really make any difference which level they're functioning from, they're all capable of doing it.

Teachers were able to observe various student behaviors to determine whether they understood the material, including the questions they asked (mentioned by 3 teachers), what they said during discussions (2 teachers), their written assignments (6 teachers), and how well they predicted results (5 teachers). They could then determine that students understood the point of the lesson from their interactions during class discussions and the questions students asked them.

> They asked a lot of questions, which is good, a lot of real good questions. Wanting to know why and how these techniques came about, and what's next?

One teacher saw students helping one another with the work.

> …if one group was stuck, I would see others teaching, sort of jumping in instead of me having to do it. I would see, "Oh, you gotta do this," and they would turn around and help each other, which is always a good sign when they're sort of taking responsibility and control over what they're doing and learning in some of the activities, and helping others out.

Another sign of comprehension that teachers reported is that students remembered and applied the information in another context.

> I gave an essay [assignment] on gene expression and I'd say 85-90% of them related a little bit, tied some of the sequencing back to it, which was good to see.

> Still to this day, someone will bring it up for some reason. They still can remember what the unit was about and what exactly was going on. And so I think that's pretty impressive that they still remember the point of the unit this many months later. I mean, it just went on too long, so I think it was pretty successful in getting the point across, just because they remember it now.

One teacher had his students complete an assignment where they had to relate the information they learned to something that was relevant in their lives.

> In my assessments, what I do is I leave it up to them to tell me what they learned and why it's important and how it affects their world.

The way in which the material was taught made a difference in how well students understood the information.

> Students always respond better to hands-on stuff that illustrate the points well than to just lecture or notes, so I'd have to say, yeah, that I always get enthusiastic responses from activities that I've used.

Utilizing varied activities to reach different types of learners seemed important to the teachers. Second to the hands-on labs, technology was named as a successful way to get students to understand the material. Interacting on the computer gave students visualizations and animations that made concepts easier to learn.

> I think [what] *Scanning Life's Matrix* did was take the actual chromosome and you could look at the sequences that have been transcribed and look at those and say, "Gee, this is where the genes for certain things are." And then if we want to look at doing medications or treatment for different kinds of disorders, preventatively or after the fact, there's where our biotechnology work may come in. And so that piece was very helpful because it did give them an understanding of that.

> They really enjoyed the computer sites that I've taken them to, kind of just wandering through some of the information, and then doing some of the interactive activities they've enjoyed. And a lot of the simulations help a lot too, I think, with them understanding some concepts.

How much students learned also depended on how much material was taught and for how long. If lessons were squeezed into the curriculum, there may not have been time to cover the new material in much depth.

> [Students understood] only in a really general sense, because of what we used it for and because of the fact that it wasn't really a whole unit. I think definitely [with] that included into the curriculum and with some of the other activities that were used in the workshop, I think that would be awesome. Those are awesome tools to use, but that wasn't a focus for me this year.

Teachers were asked about the learning goals they had for their students for the lessons using the workshop material, which obviously influenced the direction and emphasis of the lessons. The most common response, given by mostly *Cancer* participants, was that they wanted their students to learn facts about the topic and to undo their misconceptions. Teachers also wanted students to be able to relate the science they were learning in the classroom to the real world, make connections to other science concepts, problem-solve and feel like a scientist.

Only three teachers reported that their students had problems in understanding the material. A class of language learners had trouble reading a worksheet, and one teacher thought that that the students did not have enough prior knowledge to which to relate the new information.

> They have no background—they just are coming from an environment that doesn't really teach the stuff.

As discussed in the section on how teachers implemented, the adaptation of material to students' developmental and language level was an important task for the teacher in preparing to use the information in their class.

B. Gains in Student Interest in Science

Part of the mission of the BSI is to increase student interest in science and in pursuing a science-related career. Ten teachers stated that their students already held a strong interest in science, especially those who were enrolled in the high-level or AP courses where the workshop material was often used.

> My *Intro to Biotech* kids are very much interested in biotechnology, in DNA, molecular biology, genetics, things like that. So these are the kids that are really going into that, but then again, most of those students are juniors and seniors—most are seniors—and they have an idea of what they wanna do. They're taking the class because they're interested in molecular biology and genetics.

> I don't know if it necessarily had an impact on science as a career. I know that a lot of the kids are favoring a life science in college and that's why they're in that Advanced Placement class, too.

> A lot of them that come to me as juniors and seniors [are] already in that vein. We pretty much make them take three years of science, and they don't start taking electives like genetics until they're at least in chemistry, so these kids are kids that are already planning on being doctors, a lot of them, or being nurses, or just really enjoy science to begin with. So they're usually picking my elective because they have an interest along those lines.

These comments suggest that the advanced students who have already shown an interest in science have almost hit the ceiling level of interest and may not experience as much of an impact as students who are not already engaged in the field. It is difficult for the TPD workshops to target a particular group of students, especially since one teacher often teaches both AP and regular biology, for example. But it may be valuable to encourage teachers to use the material from the workshop with students from a range of backgrounds and abilities, and not just to focus on the "high-end" students with these seemingly advanced or cutting-edge topics. The quotation below comes from a teacher who used the material with what she called her "roughest" class, but who nonetheless had the best discussion.

> There was one thing in particular he said, that, I think, 90% of brain cancers originate in the lungs, and the kids are like, "Holy smokes!" So people who smoke are at a greater risk. And it led to—I mean, we just talked and talked and talked, and it's usually my roughest class, if you have such a thing in [my school system]. It's a pretty unmotivated group of kids, 'cause there is just lots of tracking that goes on in schools, but they are the best discussion class. They're truly interested, they're just—a lot of them aren't—how do you say this?—they're all fairly bright, but they just don't do much.

Indeed, a cutting-edge topic was an element that piqued student interest. Eleven teachers stated that students' positive response to the material was partly due to the currency of the topic. Generating interest, teachers thought, could be part of what inspires students to pursue the study of science.

> I see the biggest interest in biology coming from the fact that the material isn't just old-old. That it is current, there's exciting new research going on, and whatever I can learn and pass on, that seems to be the thing that moves the kids to take other classes in science and to consider science as you know maybe something they would really like.
>
> That was the big takeaway I went on and on about, the viruses that some of the strategies, that either they're helping or they're hurting. But just some of the amazing things that they're discovering about new treatments, I think, kind of catalyzed a few of them to consider it.

A cutting-edge topic also seemed to be a way to get the students involved and curious in how scientific knowledge develops.

> The microarray is new enough to students where they haven't heard of it before and even other teachers hadn't heard of it before, or may have heard of it but weren't aware of what it was. And so to hear about how so much more genetic screening could happen, and quickly—that, I think, that was important to convey.

Being current can be synonymous with being relevant to students. Discoveries that are happening now in science are relevant because students see and hear it around them. When information is new, current newspaper and magazine articles may relate to it and activate that knowledge area.

> It's new and relates to them. Molecular genetics is just an expanding field, it's so growing, and it just piques their interest. 'Cause we're reading *Scientific American* about race and is it genetic, is it not, and types of genomes that are out there, you know M-R- and A genes… so they're asking questions as we're reading through the articles, too, and going back to that.
>
> One of the first questions that people always ask me is like, "Well, using these little chips, would they ever really be used for screening people on a wide scale, or is it really just always going to be used on a research basis?" At time they were saying, yeah, it would always just be used in a research basis and they're highly specialized for the application in the lab that they're being used for. And of course there was an article that came out, I think it was in *Discover* magazine, just a couple months after my class, that the company that makes those chips had come out with a chip designed for screening the human genome on a [inaudible]. You know, that could be used as like a personal ID check.
>
> I have a lot of them that are really into current events, and so they're bringing things to me off the Internet that they're finding on stem cells and stuff like that. So I've got kids that are really interested in things along those lines, and so that's not necessarily all of them, but there's definitely a few that are out there looking at information and thinking about these things

Other aspects that lend relevance to the material will be discussed further in the next section. Aside from being current, the topics that BSI chose are often just interesting and appealing to students.

> They're really interested in the topic and they like those kinds of activities that give them an opportunity to see how it's really done. I just used, this past week, one from a previous workshop on DNA sequencing, that took it from actually how DNA sequencing is done to putting it into a … search on the NCBI site.
>
> Many of them brought me literature and stuff they had read and they were fascinated with it. Of course, I did show them the movie *GATTACA*—not the whole movie, just a couple pieces. And again, what they're interested in is, "Gee, can we do some genetic engineering manipulations?"
>
> …because a lot of them, you know, it's a big mystery. Cancer—like, "Oh my god, we're gonna die." And so they're very interested in it.

Again, teachers saw evidence of students' interest in the behaviors that they observed, such as the questions students asked, and whether they remembered the information and applied it to a later situation or shared it with friends or family.

> Willingness to do research on their own, going beyond what they were introduced to. I had kids who went to web sites and they read, they brought, they brought in newspaper articles and magazines articles. I had parents tell me that the kids were asking great questions at home.
>
> They get very, very, very excited about things that they're actually doing. If it's like a story like that, or a lab or anything like that, they really, really enjoy those kinds of things…. Because they'll ask questions and they'll actually do it... 'Cause for the most part when I do things like this, I make sure that they come up with their own questions and predictions and then they work through their own labs, so they're really excited to see how they're gonna turn out. They really like that. I like that. It's really fun.
>
> We had a lot of good discussions, and I know they brought it home. 'Cause we had a little open house—some of the parents came by and said they were intrigued by the discussion that the kids were bringing home.

Of course, what piques a student's interest is often a matter of personal preference, and three teachers reported that some students were more enthused by the material than others.

C. Gains in Seeing Science as Relevant to One's Life

According to the teachers, the workshop lessons helped many students realize how science was relevant to their own lives. This was, as previously stated, a learning goal for many of the teachers. It helped them take a scientific perspective and gain knowledge about a specific issue that affected their lives, such as genetic origins of disease, water quality, and cancer.

> …especially some of the kids that I have now, you know either have some genetic conditions in their family or in themselves that they're thinking about.
>
> I think that using cancer in the classroom makes it relevant. I mean, cells and organelles, they learn about those things, and it doesn't really have a—they, I don't think, really see. They know they're made of cells, but when they see something like a disease, and then

> they get a lot more interested in it, I think that does bring home the relevance. So yeah, I think in that way, it reminds them that science is relevant to their lives, and because they know they have the potential of getting, of having cancer, their relatives or their friends—it's relevant.
>
> A lot of them super-relate because their grandparents have cancer or it runs in their family. I have them do a family tree of diseases. So they know that, "Oh yeah, there are people that have died of this in my family or on my block."

In fact, cancer and disease were particularly powerful topics, and some teachers chose to use these workshop topics specifically because these topics could make a compelling and personal connection between science and students' lives.

> …because I know it has touched some of the kids in my classes, some of our kids. One of our students does have cancer, and then a couple more have either lost parents or have parents with cancer. So I thought it would be really relevant.
>
> Cancer, I think, is really fascinating to everyone. Everybody knows someone who's been touched by it. And I participated in development of one of their cancer units, and that was interesting too. It brought it to a personal level, so you just, you know, you ask the students if they know of anyone who's had cancer in their family or friends or whatever, and everybody has. And so they usually have a real curiosity about it, and you know that's something that you always wanna take advantage of. So yeah, I think cancer has to be a part of any biology class in some way.

While taking advantage of students' curiosity, teachers did take care to be sensitive to the emotion that such personal connections could engender.

> I had talked to that student's mother, just to see about his comfort zone. As well as the other student, his father was really seriously sick with cancer. I spoke to both of them just beforehand to see, if, you know, what their take was on it. And they were more than happy to have me do it. Because the more you can tell them, the better, and actually the one boy who has cancer, he offered to bring things in and talk about it too.

In sum, teachers saw evidence that both cutting-edge content and personal relevance could increase students' interest and engagement in science, for students at all developmental levels. For them, generating interest was part of the value of the workshop materials.

> But it was their favorite; most kids said it was their favorite unit. And again, I think it's because it's an area they don't know that much about—they haven't had background information. To me, the value of something like *Scanning Life's Matrix* is to be able to take the concepts of genetics and apply it to the human body, something they personally are interested in at that level. And …our whole goal in high school education is to spark their interest. Once you do that, once you hook them with that interest, they—the bright kids and the ones who may not have done so well before—are able to kind of take that further on their own.

IX. Permanence and Sustainability: A Single Experiment or Lasting Change?

We have discussed teachers' reports of their implementation of classroom materials, their decision-making and preparation processes, and their observations of student response to the workshop materials that were adapted to the classroom. All of these are evidence that the

workshops do have an impact both on teacher classroom practice and on student learning and interest. For these changes to be even more significant, however, they need to last beyond one semester's experimentation in the classroom. Thus we explored both teachers' intention to continue (or not) their use of particular workshop materials such as those that they had already used in the classroom, and evidence of larger-scale, lasting influences on their classroom practice and philosophy.

A. Plans for Future Implementation

Twenty-eight teachers (90%) stated that they were planning to use the information from the workshop again. Of the other three, one was discouraged by his experience using the entire case study and two had yet to decide. Almost every one (25 teachers) of the teachers who stated they would re-use the material described alterations they were going to make the next time they used it, including four teachers who planned to add more use of technology such as the DVD or PowerPoint lecture. In addition to the time spent up front preparing the lessons and deciding what activities and information to use, these teachers assessed their classroom experience and looked at students' responses to the aspects of the workshop that they had applied in class. They then thought about what they might want to add, edit or omit the next time they taught the unit.

> I might try to do more of the stuff in the envelopes, or the bigger activities, depending on time. I just have to see how they do, and I'm going to revamp for next year anyway.

A large number of teachers (21) mentioned that they wanted to expand on what they had used the first time. This is a strong indicator that their initial experience was very positive and they found it valuable enough to dedicate more class time to the material.

> I would like to try to do a little more with it, which means I speed up other areas—try to allow more for it.

Even though teachers had had the opportunity at the workshop to try many of the activities themselves, it appeared to be difficult for them to predict how their students would respond. So the first time they used the material, it was seen more as a trial. Also, depending on the timing of the workshop relative to the coverage of relevant content in their curriculum, teachers might first try to squeeze in the materials at the end of the year, but plan on using it as a whole unit for their next class.

Their projected changes may also reflect teachers' sense of how their curriculum is in constant fluctuation. Teachers often anticipated changes based on new courses they might teach or future modifications of the standards or tests.

> Well, what I'll do next year is—because cancer is a state standard, and we're doing the science CSAP—I'm assuming I'll use it sooner in the year.
>
> I sure hope so—CSAP permitting. We're now engaged in battles in my district to decide what will be pruned out and what will be retained. And molecular biology, I may have trouble expanding it the way I want to.

As noted earlier, it may be helpful to call teachers' attention to the relevance of workshop content to state standards and assessment frameworks, both to help them defend decisions about their course content and to reduce misconceptions they may have about these perceived constraints.

Teachers also planned future changes to their lessons simply to counteract their own boredom with repeating the same lessons year after year.

> And there are some activities that we've done that necessarily aren't very good, and I try new stuff every year, otherwise I get bored.

Teachers were frequently making changes to their lesson plans from year to year, so the notebook that the TPD workshops provided with activity descriptions and materials became very helpful in keeping track of possible options for what to incorporate.

Only two teachers said that they would cut back on what they had used initially: one because of the cost of materials (test strips) and another because of the class time involved in using the entire case study.

B. Broader Changes to Classroom Practice

We have reported a high rate of implementation and similarly high rates of planning to continue. However, as the above discussion indicates, plans to continue classroom implementation of any particular activity may not be a reliable measure of impact in the long run. Many factors can influence whether a teacher can and will continue to use a particular activity learned at the workshop, including changes in an individual's teaching load or to a school's course offerings, shifts in emphasis in externally-imposed curriculum guidelines, and the teacher's own evolving interests.

In addition, we have seen that many teachers viewed the workshops as a place to "shop" for new activities to substitute for or supplement things they were already doing. Their emphasis on this both as their motivation and as a workshop outcome suggests that the workshops may most frequently spur small, accumulative improvements to teachers' skills and lesson plans—what Thompson and Zeuli (1999) call "additive" professional learning, addition of new skills to an existing repertoire. However, we also sought to discover whether the workshops prompted any broader reconsideration of the place of a topic within the discipline or of the choice of teaching and learning approaches to a topic—changes that might be described as "transformative" professional learning. As described by Thompson and Zeuli, this refers to substantial changes in deeply held beliefs, knowledge, and habits of practice. Science education reformers have argued that such broader and deeper changes are required to achieve real progress toward national goals.

In this section, we examine the influence of the workshops on teachers' overall classroom practice—not just use within lessons of specific content or activities received at the workshop, but changes to the curriculum itself (e.g. inclusion of new topics or changes in emphasis on topics); changes in the teaching and learning approach to a particular topic (e.g. to address students' conceptual difficulties); or changes in overall teaching style (e.g. toward methods espoused by the TPD workshops, including inquiry and hands-on strategies, not only for workshop topics, but for other topics).

1. Changes in Course Content

As we have discussed, it is evident from the interviews that teachers did incorporate the information that they used in the workshops into their classes. Many teachers attended the workshop because of their own pre-existing interest in the topic and belief that it would appeal to their students. They seemed to attend with the established plan to fill their lesson plans with activities or information from the workshop, already knowing or assuming that the topic would be a part of their curriculum. A similar number of teachers, however, became convinced upon

attending a workshop and getting acquainted with the activities or content that it was important to teach a particular topic to their students, and that they had to make room in their curriculum to incorporate this new material.

Twelve teachers stated that the workshop topic was new to their class. When asked about how the workshop affected their teaching, the addition of the topic was frequently the first impact they mentioned.

> I hadn't used that before. That's why it was interesting going to the workshop.
>
> I wouldn't have done it without the workshop, so it influenced it a lot.

One reason these teachers decided to add the topic to their curriculum was an increased sense of comfort in teaching it. This was especially necessary with up-to-date topics or currently changing areas of research, because teachers have little or no experience teaching it to their students. They may not have been exposed to these new ideas in their own, earlier, biology education.

> I didn't do much with it the year before, 'cause I was a little intimidated about how to present it. I learned some ideas of what's there now….

Another group of twelve teachers stated that they had planned to teach the topic prior to attending the workshop, perhaps drawing from their prior experience teaching the subject.

> We always touch on cancer, because there's so much interest. But I haven't had the information with which to answer—just this time.

Additionally, six other teachers who planned to use workshop information said that the workshop had persuaded them to go into the topic in greater depth than they originally intended.

> I taught the same content before. I've just added whatever activities I can get from the Initiative.
>
> I actually teach quite a bit on cancer… But I went back and reviewed some of the new information that I got, just to show them that science is constantly changing. And teachers have to go learn too. So I went back and reviewed and cleared up some of the stuff I taught that wasn't really wrong, it was just not complete.
>
> I don't think I've ever spent a whole lot of time on cancer other than when you talk about cells, and it's just growth in cells that has gone awry. I mean, I might spend a day or two talking about cancer, but I've never gone into greater depth than that on cancer.

In sum, twelve teachers reported adding new topics to their curriculum and six increased their depth of coverage. The others reported no changes to the content of their curriculum following the workshop.

2. Changes in the Teaching and Learning Approach to a Topic

Even if the workshop did not alter the curriculum content (or could not, because the topic was already being taught), teachers' participation in the workshop still influenced how they presented a workshop topic. Most often, the workshops provided more student-involved or inquiry-based activities on a topic that teachers had already included in their curriculum. Teachers were able to substitute new, more active learning strategies for their previous approaches to a topic.

> In the past when we've had more time for it, I have done a lecture on cancer, which gets a little dry, just to go blah, blah, blah about cancer. What I liked about the concept was here, you could talk about a little bit and then see the pictures and really see the visual impact of it, which I hadn't had before…. It seems it's something the kids are kinda interested in, but it's a lot of just talking about statistics and things, and I think it would really add some good visual impact and some student-centered stuff where they're then taking the info and applying it to things.
>
> I would have taught it anyways, but not in the way that it was presented at the BSI workshop. They gave me new ways to do it.

Seven teachers reported new approaches through the workshop-provided technology resources that they were able to use with their students. Materials such as the CD-ROMs or DVDs were useful for teachers when they provided easy opportunities to show visual aspects without a great deal of set-up time or expense. Use of a prepared PowerPoint presentation was an easy way to shape lectures and make them more captivating for students.

> I really liked the PowerPoint. That helped a lot to have that already made.
>
> I think that the PowerPoint really enhanced, you know… having those visuals really helped, and the kids enjoyed the PowerPoint slides.

Searching the web for teaching resources is very time-consuming and often futile. So being directed to legitimate science web sites was very helpful, even if students did not look at them in class, such as this teacher who just informed her students of the sites.

> I didn't use a lot of what they had done through using computers and databases online, but just being aware of it, I was able to let students know that that sort of thing was happening out there in the work world, and I probably wouldn't have done that otherwise.

Five teachers mentioned an increased hands-on emphasis that stemmed from their experiences at the workshop, and another mentioned using inquiry.

> Probably a little more interactive than it would have been, instead of me just babbling on.
>
> I've taken so many of the workshops and you've always got the inquiry activities in there. That one didn't augment my understanding that much, but it did give me some activities to add a little bit of spark to the teaching the unit.
>
> It gave me the idea for how to do an open-ended one [activity]… They had an assistant go out and collect water and we were supposed to test that … so I did that same sort of thing where I had samples and the kids brought in samples and we ran it all through the test for coliforms and the predictions to see, "Do you think there's anything in there or not?"

Significantly, half of the teachers we interviewed from the *Blue Baby* workshop said that they otherwise would not have presented the information in the form of a case study.

> It gave me a really good way to just show it as a story, and how all different things become involved, so that was good.

That workshop also encouraged one teacher to try to use a case study in an upcoming unit.

> The *Blue Baby* kind of introduced us to case studies, 'cause I hadn't really been doing those. One of the teachers at my school has been—she really likes them, so that was like a new technique too…. I'm going to use it—I haven't used that with these environmental [concepts], so I'm going to try that.

For some teachers, participation in the workshop changed their perspective on the topic. From the *Cancer* workshop, one teacher described how the empathy of a presenter made him more aware of how to deal with a sensitive issue.

> The presenter was very sensitive and he was obviously very caring, and I think sometimes when you're talking about a subject you try to be objective … about it. You forget about the personal aspects, and I think he was really good at sort of bringing home the pain and the suffering that happens with cancer and then the emotional sensitivity 'cause people are familiar with it through personal experience. To always kind of be sensitive to that, so it wasn't really a scientific thing as much as maybe as it was a personal… to be aware that it's kind of a sensitive subject for people.

Only one teacher mentioned that the provided resources and handouts added to their presentation of the topic, but it is obvious from their discussions of classroom implementation that these materials influenced other teachers as well.

Finally, in addition to these specific changes to their teaching and learning approach to the workshop topic, eight teachers described a more subtle change. For them, the largest impact was on their own additional knowledge and the confidence that knowing more gave them.

> I wouldn't say that they workshop influenced my presentation of it. It gave me the content.
>
> I think just that it made it clearer in my mind, how it worked, and so that I would be able to explain it better to the kids.
>
> It kind of energized me a little bit, because it's such a fascinating area. I think the more interested you are in a topic, the better the kids respond… It gave me more information and better information, and just made it more complete.

The resulting changes to their presentation of the topic might be subtle, but nonetheless important to teachers. The personal importance of updated and increased knowledge for teachers and its effects will be further discussed in Section X.

3. Changes in Teaching Style

We have just noted specific changes to teachers' approach to the teaching of workshop topics that can be directly attributed to teachers' workshop participation. These are the same changes that are detailed in the discussion of implementation earlier in the report. Changes to teaching style would include changes in approaches to *other* topics—for example, use of the case study approach in *Blue Baby* might prompt development or use of available case studies on other topics. A positive experience with student-centered, inquiry approaches on one topic might spur greater use of these approaches throughout the school year. However, although an explicit goal of the BSI workshop program is to promote the use of inquiry methods and hands-on teaching and learning strategies, most teachers hesitated to claim that a TPD workshop had significantly affected their overall teaching style. Seven teachers stated that the workshop did not prompt any other changes in their teaching. This may be an indication that the influences of the workshops

tend to be very focused on the particular content included. Overall, we found that teachers did not often discuss making connections to their teaching practice as a whole—a point to which we will return.

One explanation for this lack of effect on teaching strategy may be that the audience attending the workshops is already committed to and skilled in the use of these strategies. Indeed, the teachers whom we interviewed described their typical teaching style as already being in line with the BSI philosophy.

> I'm not sure that my style changes, but I have richer activities to offer and that makes a difference. I don't think my style specifically changes …I mean, most of the teachers who go to these things are already there to look for activities and exercises their students can use in class, so already most of the teachers already have a style that incorporates that, otherwise they wouldn't find so much use in the course.
>
> Teaching style: it probably gave me some options, but it kind of fits my teaching style, and that's why I liked it. I try to use media, written, research, visual, oral… all of those things, activities with kids, activities and lab things. So, it fits my style because it was a multimedia approach in that there were activities and the DVD and lecture.

It was difficult for teachers to point to specific influences that affected the formation of their teaching style, but it is quite possible that a history of attending the BSI programs had previously helped to shape their practices and philosophy, as one teacher articulated.

> If I hadn't taken BSI workshops before, yes, it would have made me focus much higher on inquiry. But having taken so many, that's such a part of what I do now that the answer on that particular workshop would be no, it just reinforced what I already do…. Getting the inquiry into your classroom is the major theme of all the workshops.

Likewise, sixteen teachers reported that they typically used a lot of hands-on labs with their students, and four teachers that they based many of their lessons on inquiry.

> We tend to enjoy the labs more than anything else. They like micro-pipetting, they like setting up gels, they like being able to take photographs of their gels and things like that.
>
> In *Introduction to Biotechnology*, that's almost entirely inquiry-based. I do very little lecture in that.
>
> I try to use as much as I can [of inquiry] in my classroom, 'cause it really is usually the most effective way for the kids. Inquiry is a little difficult sometimes because kids …they're not used to trying to find out the answers on their own. They want to know the answer. And it makes them very uncomfortable if you put them in a position where, "Well, no, you need to figure it out, and maybe there's not really a right answer." They get very uncomfortable with that—but many times they just want the right answer, so inquiry is a wonderful idea, and it's great, but it sometimes is a struggle to have them do it, because they're just very programmed that there's a right answer.

It is also possible that the TPD workshop audience does not need to be convinced of the value of inquiry approaches. From the teachers' descriptions of their motivation to attend the workshops, we already know that they often signed up seeking hands-on activities that they could easily bring back to their own classroom.

> I would say that it gave me information so that I was able to add to existing stuff. But I think my style is, I don't wanna say set in stone, because the style is fluid, and the fluidity, the change, is set in stone, if you know what I mean. So it gave me new information that I could layer on top of what's already going on, but as far as teaching me something like a new technique that I would try in the classroom, I'd say no 'cause I've been trying to keep kids active rather than in their seats for a long time now and, and that's why I like the BSI workshops is they always give you new things to do.

They represent themselves as a high-end group of skilled and savvy inquiry practitioners. In this respect, our interview sample from the TPD workshops resembles our teacher sample in the Science Squad study (Laursen, Liston, et al., 2004), who likewise described themselves as already practicing inquiry methods and using extensive hands-on activities. However, that sample was deliberately chosen from among "frequent users" of the Science Squad, who might be expected to explicitly value the inquiry strategies used in both that program and the TPD workshops, while this sample appears to be more representative of the TPD workshop population as a whole.

Thus, if this representation of the teacher population in the workshops is accurate, a main outcome of the workshops appears to be in supporting this "shopping" strategy for a high-end group. Their needs are met by the workshops as long as the workshops provide an interesting array of topics and a growing selection of well-designed and tested inquiry activities from which to choose.

However, national data make it evident that such high-end teachers are not by any means the norm (Horizon Research, 2003, and references therein). This interpretation raises the question of why the workshops do not appear to recruit participants who are new to inquiry approaches. While it is important to support excellent teachers—such support may indeed keep them in the field— the overall impact on the quality of science education from working with this population may be relatively small. To have greater impact it may be necessary to offer other types of programs to attract novices and the "unconvinced," or to seek ways to gather a wider spectrum of participants in these workshops.

Another interpretation of this finding of little impact on teaching style is that teachers are not asked in the workshops to examine their teaching style, to reconsider their beliefs about teaching and learning, or to consider any information that encourages their thinking along these lines. In the earlier quotations, we see some slightly circular statements that assume a direct equality between their teaching and learning beliefs and classroom practice:

> …most of the teachers who go to these things are already there to look for activities and exercises their students can use in class, so already most of the teachers already have a style that incorporates that, otherwise they wouldn't find so much use in the course.

However, in other comments, teachers described more directly the mix of classroom activities that they use, and their reasons for these choices. Some cited the importance of maintaining a balance in their lessons between the doing of science in hands-on lessons and less interactive presentations of content.

> We do a lot of hands-on stuff. We do some computer activities. Usually in the class, mostly what I try to do is have us do enrichment activities, and then I assign them reading

> and study guides to get the basic information, and then we'll discuss it as necessary… Like the microarray thing would be an enrichment activity. We do different labs.
>
> I don't want to cut the content, and I realize sometimes it's hard to do labs that seem like; "Okay, we've got to do a lab". But I'm not necessarily… I would be three quarters/one quarter lab, and it's not like I don't want the labs. But you know, just to have hands-on activities for me, I don't need that many, but I do need content.
>
> Hands-on activities in general work well for them, so I try incorporate that with… that's also, you say, very good for the kids, but it's more work for me, and usually …Sometimes it's nice for them just to have class, you know, see it work and then the hands-on activities. A little bit of both is ideal.

One interpretation of comments such as these is that their classroom practice, as teachers describe it, reflects a somewhat more qualified commitment to inquiry strategies than is indicated by the earlier quotations about their teaching philosophy. Such contradictions between espoused beliefs and actual practice have been reported often in the literature (Horizon Research, 2003; Kane, Sandretto and Heath, 2002; Weiss, 1997). Rather than organizing their course around students' learning, the course may be organized around conveying "basic information" plus "enrichment." Labs may be viewed as add-ons, perhaps focused on developing skills, rather than as means for teaching fundamental concepts, and workload issues loom large in teachers' decision-making. While we do not dismiss the practical issues of implementing inquiry, the research on learning does not support an approach in which inquiry is relegated to "enrichment" (Bransford et al., 1999). Thus it may be worth considering how teachers' understanding of inquiry, the research base behind it, and its incorporation into real classroom practice might be further enhanced in the workshops. While this may be a specific focus of some workshops, it may also be possible to develop strategies that would prompt participants to link the specific content and activities to principles of learning without shifting the overall focus on content and activities (which, as found in this study, are both attractive to teachers and provide strong benefits to them).

We note that, while most teachers reported no effect on their teaching styles, primarily because, as they told us, they were already committed to and skilled in using inquiry strategies, seven teachers did note some changes in their teaching practices due to their workshop experiences. Changes included the integration of more technology, using the case study approach and using more inquiry. One teacher tried to make more use of technology in other subject areas, within her scheduling restrictions.

> I'm trying to get more and more film clips that I can incorporate in along with lecture, and otherwise there are some things that we just don't have time to do, some of the hands-on stuff, just because it is AP, we're kind of up against the calendar all the time. But trying different ways of presenting it and using some of the video material and some of the information has been really useful.

Two other teachers mentioned that their experiences using technology, such as the PowerPoint presentation, made them feel more comfortable about applying it to other lessons. However, it is not clear whether these changes are solely a change in the means of delivery or thoughtfully based on evaluation of their effect on students' learning.

The *Blue Baby* workshop had much more of a pedagogical impact because it introduced the case-study approach to many teachers. More than any other workshop in the three we examined, teachers from that session mentioned the pedagogical methods as something they took away that influenced their teaching.

> The *Blue Baby* thing kind of introduced us to case studies 'cause I hadn't really been doing those and one of the teachers at my school has been--she really likes them, so that was like a new technique, too.
>
> I did start looking up other case studies to see if I could use them.

Only one teacher mentioned that her experiences at the BSI workshops over many years have encouraged her to incorporate more inquiry. In sum, it is notable that there were so few changes in overall teaching style that teachers could trace back to the workshops. Teachers never stated that they were influenced by the models they saw in the workshops. Reflective comments or realizations about student learning of workshop concepts were rare, suggesting relatively little development of what Shulman has called "pedagogical content knowledge" (Shulman, 1987). Although many teachers claimed that they already used methods that the BSI promotes, this finding raises the question of how open the teachers are to evaluating their own practice and applying new pedagogies modeled during the workshops rather than just adding new content that they learned. We argue here that it may be important for the BSI to more clearly emphasize the linkages between the workshop content and pedagogy and the research on learning that supports different methods of teaching content. While inquiry methods are modeled (apparently convincingly) in the workshops, modeling alone may be too subtle, and a more explicit approach may be needed to help teachers make these links. It may also be interesting to consider incorporating strategies such as peer coaching, lesson study, action research, and other ways of helping teachers attend to student learning as they apply what they learned from the workshops.

X. Other Impacts

We have discussed in some detail the effects of the workshops on classroom teaching: changes in content, teaching strategies for the content, and overall teaching style. In addition, teachers reported: gains in their own content knowledge, formation of new professional connections, and spreading the impact of the workshop by sharing their learning with other colleagues. These outcomes include both gains for the teachers as professionals, and expanded outcomes of the workshops through the participants' sharing with others at their schools.

A. Gains in Teacher Content Knowledge

Nineteen of the 31 teachers commented that they, as participants, learned a lot of science content. Compared to other workshops, teachers thought that the TPD workshops were offered at a particularly sophisticated level.

> They're higher-level and they're taught by professors, which really helps. And the professors at the BSI, they're so nice and so friendly, and they know what they're talking about. And they base it on real science and so they're amazing. I love going. I literally sign up for every workshop, so I don't know what I would do without them.
>
> I think compared to most of the classes I've taken it's been the most… it was definitely the most advanced as far as the information.

While a few of the teachers had difficulties applying the high level of information to their students, most teachers appreciated the depth to which they were able to explore a topic, especially one that was scientifically current. They believed that their increasing knowledge benefited the students in ways other than just passing on that same level of information to them.

With an increased level of content knowledge, teachers felt more confident in teaching and answering students' questions, more capable of finding creative ways to present a topic and more excited about the subject matter. Even teachers who thought they were already well-informed on a topic and knew how to teach it were surprised at how much they learned.

> I thought I knew quite a bit about cancer, to tell you the truth. The day of [the workshop] I was thinking, "Oh, I should just cancel, I know enough about cancer." So I'm always surprised, what and where I can use things. I don't think I've ever been to one that I didn't learn a great deal and even if I don't use it right away, I think, "Oh, I have something on that." I don't think I've ever been to one where I haven't been surprised or learned something.

Seventeen teachers stated that they felt more comfortable teaching the topic from the workshop to their students. As noted, one of the main motivations for teachers to attend is to enhance their own knowledge base. Repeat participants are familiar with the TPD workshops and enter with the expectation that they will learn science content.

> I think it was a course that really was helpful in terms of just my own knowledge about cancer and enhancing my own feeling of what was involved and things like that, so it provided me with a lot of background information.
>
> I think having this information presented at such a high level and having to wrestle with it, then I really, thoroughly, understand the topics I'm presenting, so I just think that's just critical for a teacher.

Increased understanding improved teachers' ability to present the information to students and answer their questions.

> I go to deepen my understanding of a subject because I think then I'm just better at presenting.
>
> Kids ask questions. And if you don't have the background then you can't answer them accurately and correctly. And so no matter what, I'd rather have it on a higher level and then I can bring it down. If you got it on too low of a level, then you don't even challenge the kids, let alone yourself.
>
> I think just that it made it clearer in my mind, how it worked, and so that I would be able to explain it better to the kids.

Especially for teachers who did not have a lot of education or experience in the field or who had been out of school for a while, learning content was a large advantage of attending the workshops.

> I'm not a bio major. I was in middle school for ten years, a teacher of all sciences, and then before that, just lower level… So this has been where I've gotten a lot of my content other than picking other workshops too and reading, to catch up with biology, 'cause it really, from when I went to college, took off.

Getting access to current information was valuable, especially when a lot of other teaching materials are out of date.

> It's definitely given me a stronger background in some areas that I wasn't very strong on 'cause it's been so long since my college course itself and things have changed so rapidly. So that gave me a lot of confidence at some of the more recent developments, in terms of addressing them and bringing them and talking about them.
>
> One thing it did was make me aware of how fast that field is changing… I've been out of college for about seven years, and I took a couple biology classes and things are so much different in that field now, and I'm sure they're going to continue to change very rapidly. If you're not staying current or reading journals or something, you know you're going to be totally out of date in a couple years.

However, there were far fewer comments from teachers about gains in understanding the nature of science—how science works. One exception was the following teacher:

> I thought what was so impressive is how the lecture really involved the process of science and forming a hypothesis and research, which I'm at a disadvantage of 'cause I've never been a researcher in a lab or something. So I think it's wonderful to be exposed to people who do research and go through the process of science and share that information with me, although sometimes it is hard for me to transfer that.

The absence of such comments, relative to gains in content knowledge, may be significant. As this speaker points out, most teachers have not done research, and may not understand that science is not about specific factual knowledge, but rather a process of developing and refining knowledge. BSI might use its strong network of collaborating scientists, for example, to emphasize the process by which new discoveries are made, as well as share the new discoveries themselves.

Not only the content was new to some teachers: having the opportunity to practice and see instructional technologies at work allowed teachers to gain a degree of comfort that increased the likelihood that they would use them in their classes.

> I'd had it in other classes but retuned it so I actually felt comfortable to use it. I don't know if I directly took what they gave me, but I used some of what we did…It made me feel more comfortable to try it and we did okay with it.

The teachers thought that some aspects of the workshop were more for the learning of the teacher participants than for their students, but felt it was still beneficial for teachers to learn the content, even if they are not going to teach at so high a level to their students.

> A lot of it was more for us than for using with our students. A lot of it was above them, but I've used some of it, and I've used some of the ideas in talking to the kids.
>
> Now we talked about this at the workshop, and the instructors recognize that a lot of the stuff we were doing was stuff that we wouldn't use with our kids, but it was for us, to help us learn and understand it better so we do a better job with the other stuff.

Being intellectually stimulated at the workshops made teachers excited and this enthusiasm affected other aspects of their jobs.

> That's the primary goal, is if I can be current and excited then I transmit that to the kids. If everything is the same-old, same-old, then you get dull in a hurry. Kids get excited about new stuff and I'm getting my new stuff there.
>
> I think it makes my teaching more intellectually exciting to the kids because I'm so interested.

Changes in teacher knowledge and attitude are sometimes ignored in an evaluation of professional development, with the focus instead on measurable student outcomes (Guskey, 2000, p. 121). But we argue that it is an important consideration when investigating the effects of TPD, especially the longer-term impacts. The teachers we interviewed claimed that they learned a lot of science content and were able to stay up-to-date, confident and excited because of the workshops.

B. Making Professional Connections

As evident in the next section, one way to strengthen professional connections is when workshop participants shared the information they learned with other teachers at their own school. Teachers at the BSI workshops were also able to discuss ideas with the other attendees and form new relationships across schools, districts and towns.

Having a venue where teachers from different schools can interact is rare and a valuable experience for those in the profession. Being exposed to different methods of teaching, communicating with colleagues and engaging in a productive way is a strategy that may help to increase job satisfaction. Isolation in a job has been found to be a contributor to burnout (Colgan, 2003). Although not many, four teachers mentioned ways in which they connected with other participants, for example, by sharing course curricula.

> One of the participants I talked to, 'cause she taught a genetic engineering class and she kind of shared her curriculum with me.

Another positive connection for teacher participants is the link with the university. They are exposed to research, interact and learn from notable scientists, and gain access to resources and materials not normally available in K-12 schools. A number of teachers from the *Cancer* workshop commented positively on the lecture they heard from Dr. Macintosh, an expert in the field, in the surveys and briefly in the interviews.

> He's just brilliant, and he was so interesting to listen to, but he pretty much just gave us a lecture like he would his college class.

The benefit of making external connections might be further enhanced by providing more formal opportunities within the workshop to share ideas or through follow-up sessions that specifically invite teachers to share their own ideas and discuss challenges in implementation. Three teachers encouraged the BSI to provide follow-up workshops or "refreshers" so they could really raise their understanding and teaching ideas in a content area.

> Just a second time around. One exposure, and this material is pretty complicated, something with the same learning objectives, but maybe a different activity or different things.

There, teachers could also discuss their experiences teaching the information from the previous workshop, which may be helpful in increasing the focus on pedagogy and teacher collegiality.

C. Sharing with Other Teachers

Eleven teachers reported that they shared the information they learned at the workshop with other teachers at their school. This often occurred within a tightly-knit department where, for example, all the biology teachers co-planned and tried to teach the same curriculum in their classroom.

> And then I share stuff. We have a real, real great science department. If someone shows an interest, I'll tell people I went to this and, "Hey, I got some great activities and da, da, da," and if no one asks, then I don't force it on people. But if someone does, we're a really good department in terms of sharing. We're not incredibly competitive. We just truly do have a—I'm blessed with a group of people that have the best interest of the kids at heart.
>
> At that particular level we have five or six teachers teaching it, and we do planning together, and we agree on what labs and what content we're gonna be covering, the sequence and that sort of thing. So I make proposals about what we're gonna be covering and how it's gonna be covered and that sort of thing, and so they also tried similar stuff.

Getting excited about new content seemed to provide teachers with a means to initiate professional conversations. Workshop participants can be viewed as experts on certain topics and they might be approached by other teachers in their school for assistance and ideas, as in the following example.

> He (a fellow teacher) was looking for a way to make mitosis more meaningful, rather than just memorizing and not understanding why. And so I helped him understand about how to use it with cancer and he really appreciated it.

Six teachers shared the equipment or resources that they received from the workshop, such as the notebook of activities or, more commonly, the CD of course materials.

> That CD was perfect, 'cause it had lecture notes… and then some kind of overheads on it—It's just really good. And then the case studies, so I've sent it to a different environmental science teacher and told him he could use it and the whole binder.
>
> I handed over a notebook to a teacher who teaches the Advanced Bio class, and I know she was using some of the information.
>
> I had wound up with an extra set of videos somehow… I gave those to the other main biology person too. We're all good about collaborating and sharing stuff.

For those who stated that they did not share the workshop content with anyone at their school, many teachers indicated that there was nobody who taught similar enough content at their school who could make use of the information.

> Not that particular one, because I'm the only one that teaches the honors class. And no one else would teach that. It's too high level for regular biology class.

Some doubt was expressed about whether the teachers with whom they shared the workshop material would actually use it. A few teachers believed that spending the day learning at the workshop was necessary before really feeling comfortable teaching about a topic.

> The workshop is such that you really have to attend it before you have a vision of what it is, of what it can offer. Perhaps individual exercises I might be able to share with other

> teachers teaching some other subject, but generally speaking, I've always found it daunting to try to teach it without having gone to the workshop… It was a two-day workshop, so that's not something you can just pass on to another teacher sort of easily. Once I have tried some things, and they work, and I can see how they could be adapted without necessarily having the whole course, I might feel more inclined to pass something on, but I wouldn't do it just straight away.

In this situation, instead of sharing the information from the workshop, former participants encourage teachers at their school to attend TPD workshops on their own.

> They're a little intimidated yet. When I see it show up again, when I get a brochure… I'll say, "This is something you ought to go to."

Word of mouth is a strong recruiting tool for the BSI and a way that many of the teachers we interviewed got involved in the first place. A strategy for expanding the audience to include teachers less committed already to inquiry might be to issue special invitations to the colleagues of past participants.

XI. The TPD Workshops as Compared with Models from the Literature

In this section we will use models of evaluating and designing professional development as a framework to examine the TPD workshops offered by the BSI. We then use the components of these models as criteria for effectiveness: In which respects are the TPD workshops most effective, and where can they be improved? This section incorporates the implications of our findings for program improvement, including specific suggestions derived from interviewees' advice and some recommendations from the evaluators.

A. Evaluating Professional Development

Thomas Guskey is considered an authority on this topic (Guskey, 2000). In his model, there are five critical levels of evaluation of professional development. While these levels are intended to guide the design of an evaluation, they can also be used as suggested areas in which to examine the efficacy of the program being evaluated. Guskey's levels are itemized below. At each level, we describe the information gathered in this study—what we know about the program at this level—and then summarize our findings.

1. Participants' reactions

The first level of evaluation focuses on how teachers liked the workshop and whether their expectations were met. It asks if teachers felt their time was well spent, if the logistics worked, and if the content made sense and was useful.

Much of the data for this level of evaluation comes from the initial post-workshop surveys, supplemented by some specific comments in the interviews. Responses were extremely positive, the workshops continue to be in high demand, and specific feedback has been incorporated into future designs. Although different teachers came in with different expectations, all teachers we asked said that the workshop met their expectations. They were also very pleased with the new teaching space where the workshops were held, and the way they were treated like professionals.

2. Participants' learning

This level examines whether or not teachers acquired the intended knowledge and skills.

At this level, we have both survey data in which teachers rated their gains from the workshop, and extensive discussion in the interviews about their learning. In general, teachers were very impressed with the level of content that was presented as well as the pedagogical ideas they got for classroom application. Although we are looking at self-reported data, rather than an independent assessment of content learning (such as an exam or take-home assignment), it is apparent that teachers felt they learned a great deal. In the survey, teachers indicated that the workshops helped them keep pace with rapid advances in science. Many participants appreciated how the high content level helped them feel more confident in teaching. They felt they knew more than they could use with their students, but that this helped them to stay excited about the content, answer student questions and create their own activities.

3. Organization support and change

At this level, we consider the impact of the workshops on the organization and its climate and procedures. In other words, was implementation advocated, facilitated, and supported in the school? Were resources available, successes recognized and shared, problems addressed?

We have the least information about this level, but interviews did address barriers that teachers faced in using the workshop information in their own classrooms. This is also the level where BSI has the least power to affect change, at least within the current scope of this program, but that does not mean that it should not be addressed. The high rate of implementation shows that many teachers did solve these problems or found ways to work around them. Other teachers were not able to use what they wanted from the workshop because of school- or state-level constraints such as fit with the standards or lack of resources. One way that BSI is alleviating the latter constraint is by providing grants for equipment, through a separate program. Close attention to the state standards and assessment frameworks may help teachers recognize better how the workshop material relates to their curriculum, and may address misperceptions of the narrowness of those documents.

Teachers who attended the workshops reported they were able to influence their school, perhaps by helping to change the curriculum to include more current science learned at a workshop, by informing other colleagues about BSI offerings, and by sharing what they learned with other teachers. BSI might assist these efforts by making special effort to include groups of teachers from the same school or district or to offer courses that align with particular districts' programs. It is a significant but worthy challenge to help teachers recognize and overcome these organizational restrictions and to build the relationships with schools and districts, as well as individuals, that would facilitate organizational reform without abandoning the isolated practitioner. It should be noted as well that such efforts may take place in different types of programs, and that these goals may be best addressed across the full spectrum of professional development activities rather than within any single program.

4. Participants' use of new knowledge and skills

The fourth level of evaluation asks if the participants effectively apply the new knowledge and skills in their teaching practices.

The interviews strongly focused on this level of evaluation, looking at the implementation of workshop ideas and activities in the teachers' classrooms. We found a high rate of implementation—all but two of the teachers we interviewed had used or planned to use something from the workshop they attended with their students. Teachers' self-reports were

backed up by their detailed examples and descriptions of student responses. Teachers found it easy to find activities, materials or ideas to bring back to their own classroom; many had used more than one activity or element of a workshop; and every single teacher mentioned future plans to use it again or add more workshop materials. The content and the activities seemed to catch on most. Because teachers reported that they were already using very similar pedagogical strategies to what BSI presented (inquiry, labs) it was difficult to see any effect on their teaching style. A few teachers from the *Blue Baby* workshop did discuss learning about the case-study method and how they might apply that in their classes.

5. **Student learning outcomes**

The final level considers the impact of teacher professional development on student performance and student interest or confidence in learning about science. As Guskey (2000) points out, this is difficult to measure: the relationship between student learning and teacher professional development is "complex, dynamic, and affected by a variety of factors… [that] confound efforts to prove a direct, causal link between professional development for educators and student learning gains" (p. 208). Nonetheless, it is important to examine student learning, interest, or other potential student outcomes, if, after all, "the purpose of teaching is to facilitate learning" (Loucks-Horsley, et al., 2003, p. 38).

We did not attempt to directly assess student learning, affective, behavioral, psychomotor or other changes as outcomes of the workshops. One reason for this choice is the absence of a single intervention to study. While teachers experience a single, consistent intervention (even across workshops, there is a consistent level of design, preparation, and expertise of facilitation), their students experience a wide range of interventions, depending on what the teacher chose to implement and how they did it. Indeed, as we have seen, the ability to choose and to adapt materials is likely a strong positive force behind the high rate of implementation; thus constraining a classroom evaluation to a particular implementation of a particular activity in order to study it would in turn greatly limit the number of teachers who could use it. Moreover, the individual implementations that result from a workshop are small interventions, and it would be difficult to measure their impact (vs. that of a full curriculum unit or new approach). However, as the data show, the individual changes may be small, but additive: it would be very difficult to measure the impact of any one workshop on students, yet the overall effect of a teacher's cumulative professional development experience on his or her students may be more profound.

Despite the fact that we did not gather student outcome data, we did ask teachers—who are, after all, the experts on their own students—to describe how their students reacted to the lessons where they used information from a workshop and to share any observations of student interest or learning. Rather than vague impressions only, we asked for specific examples or evidence to support their statements: how did teachers know their students learned, or were interested? Teachers reported student success in learning with the materials, and gave multiple examples of student behaviors that indicated their high level of engagement and interest in not only the activities, but also the content—their response to questions, engagement in the material, and sharing it with friends and family. Hands-on activities and information that was relevant to students' lives were reported to be key factors in engaging students. Teachers considered the TPD workshops a good source for acquiring such activities and topics.

B. Principles of Professional Development

The book by Susan Loucks-Horsley and colleagues (2003) is considered the canon of teacher professional development in the K-12 arena. Their principles of professional development and their blueprint for constructing professional development experiences are widely used in the field. The principles are listed below, followed by an assessment of how well the TPD workshops appear to align with that principle and suggestions of how to further enhance that aspect of the workshops. Suggestions came from the teachers themselves in explicit statements, but also emerged from the data in terms of what was not being said or what was mentioned in less direct ways. Most suggestions are also included in the report in the relevant sections, but are gathered here to provide a more comprehensive list.

In the model of Loucks-Horsley et al., effective professional development:

1. **Is driven by a vision for the classroom.**

BSI has a common vision shared by each of its programs, that of modern, hands-on, inquiry-based science learning in a student-centered classroom. This vision is explicit, pervasive, and serves as a framework linking the different programs. The teachers who use the BSI programs seem aware of the vision and speak about how well their teaching style and philosophy corresponds to that of BSI.

To further align the TPD workshops with this principle, the BSI staff might consider:

- Reviewing for the program as a whole, and stating explicitly for the audience, the goals of the workshops—collectively and individually—so teachers know what to expect. For example, is the aim to improve teacher background knowledge or to provide hands-on activities for students? What mix of aims may be appropriate for any one workshop, and how do workshop activities support those aims?
- Placing even greater emphasis on the goals for student learning that can be met through inquiry-based and hands-on science, and communicating more explicitly the research-based rationale for these approaches.

2. **Helps teachers develop knowledge and skills.**

One of the strongest trends from the interview data is the teachers' self-reports of growth in their content knowledge. Besides providing classroom-applicable activities and materials, a strength of the workshops is the high level of current scientific information made available to science teachers. This helps teachers to feel more comfortable teaching about the topic, better able to answer student questions and more excited about the field in general. Teachers noted less influence on their teaching style and pedagogical philosophy, with most teachers stating that their practice already matches the teaching strategies that the BSI promotes.

To further align the TPD workshops with this principle, staff might consider:

- Expanding the workshop audience to include teachers with less skill in inquiry already. This might include marketing the program to other groups, offering other types of programs to attract different audiences, and/or being more explicit in focusing on student learning so that even skilled teachers are asked to reflect and "stretch" in directions that research shows are most effective for student achievement.

- Increasing emphasis on how to apply the new knowledge and activities to the classroom, i.e. on developing pedagogical content knowledge. This includes not only understanding the content, but the specialized knowledge needed to teach it, such as practices for teaching and adapting content to different learners, understanding of what makes certain concepts easy or hard for students, understanding of how students learn specific types of content and the developmental stages at which it is appropriate. This might be achieved through more explicit discussion within the workshops about the pedagogical strategies selected, ways to adapt them, debriefing in both learner and teacher roles, and time for collegial conversations. Specific topics might be coupled to different workshops or infused as a theme throughout all workshops in a given period—e.g. assessment, differentiation, misconceptions, or group learning. Assignments to earn recertification credit might place the focus more on learning than on teaching—for example, instead of a "lesson plan," teachers' follow-up work might focus on observing students, evaluating student work, or reflecting on how an activity is an example of "real science."
- Making kits available to check out that provide materials that are difficult for teachers to acquire. This might enable some teachers to try an activity with less risk than required by investing their own resources in it, and thus might encourage more intensive use of activities (e.g. a full case study instead of selected portions).

3. Mirrors methods to be used by students

In the workshops, teachers do have the opportunity to learn as their students would, and actually try out the hands-on activities before using them in their classes. However, teachers report that the workshop lessons are sometimes at such a high level that they feel unable to directly apply the same information and structure with their students. Almost all of the teachers presented the activities and content in their classrooms, but not many teachers spoke about making more significant changes to their teaching style or philosophy. Research indicates that teachers benefit most when learning opportunities focus on their teaching practice (Loucks-Horsley, et al., 2003, p. 40).

To further align the workshops with this principle, BSI staff might consider:

- Having presenters be more obvious and explicit about modeling teaching strategies and explaining the rationale behind them, especially those for working with younger or lower-level students. Teachers should understand that inquiry methods are appropriate for students at all developmental levels, but that individual activities may need to be adapted.
- Communicating more explicitly (and supporting with evidence) the value added for time spent. Doing inquiry feels "slow" in the classroom, but a depth for breadth trade-off may still be time-efficient: if students learn the material better, less re-teaching is needed in the same or later courses.
- Addressing teacher beliefs (and perhaps broadening their views) about the content level of the workshop activities, the student level for whom it is best suited to their advanced students, and the role of inquiry in advanced classes where there is pressure to teach a

prescribed curriculum.[3] Workshop presenters could be more explicit about how to adapt the workshop activities to students at multiple levels, or differentiate them within a single classroom, and workshops could incorporate more opportunities for teachers to share and brainstorm their ideas for adapting methods to their own students.

- Using follow-up sessions as a way to exchange and develop ideas for effectively using workshop ideas. Because time is a significant pressure for teachers, this may include ideas for ways to shorten activities or DVD materials.

4. Builds a learning community.

Participants, especially the core group of repeat attendees, have formed a sort of BSI-based community. Teachers have the opportunity to discuss professional matters with one another, which is often difficult to do at the workplace. Teachers are not frequently treated as learners elsewhere, but many teachers in the interviews commented on their increasing interest in current science issues by attending the TPD workshops as learners. At the least, they are able to make connections with other science teachers in their region and to the BSI staff and university scientists during the workshops.

To further enhance alignment of the TPD workshops with this principle, staff should consider:

- Developing follow-up sessions that would build upon the established community and forge deeper connections among participants as well as with the content and presenters. Teachers asked for follow-up sessions or "refreshers" on complex content, which might be combined with efforts to discuss their classroom successes and challenges, share implementation ideas and build leadership skills.
- Allowing more time for participants to discuss teaching strategies among themselves. This provides an opportunity for teachers to look at how they will tailor the activities to fit their students, gives the presenters more knowledge about what the teachers are looking for, and lets teachers engage in meaningful, professional conversations.

5. Develops teacher leadership.

Developing teacher leadership is not a central objective of this program. However, many teachers were enthused to carry ideas and materials back to their schools and teacher colleagues there. In the interviews, 11 of 31 teachers reported that they shared the information they learned at the workshop with other teachers at their school. Many teachers did mention, though, how it was difficult to instigate change in other teachers' styles and curriculum. As noted in the discussion of organizational support above, developing teacher leadership is difficult but may be a way to extend the impact of workshops as well as to more deeply engage the skilled practitioners who do attend by involving and supporting them in taking leadership roles.

To enhance the workshops' effectiveness in this principle, staff might consider:

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[3] A national panel has recently called for reform of AP and IB biology courses, which they call "out of date, too broad, and too inflexible," to align with the National Science Education Standards and to draw on recent research on science learning, pedagogy and assessment (NRC, 2002). Chemistry and physics panels made similar findings.

- Offering the same workshop multiple times to allow participants to recommend a specific and relevant topic to a colleague, or making special efforts to invite teams from a school or district, or colleagues of a past participant.
- Involving experienced participants as co-leaders of a workshop (e.g. in leading discussions of implementation and adaptation, helping facilitate activities they have used) or as coaches for participants planning their workshop implementations. Again, this role might be effectively used in a follow-up session.
- Continuing to provide materials that are easy for participants to share with others, such as the DVD, PowerPoint presentations and a notebook and CD of activities.

6. Links to the system.

Teachers reported difficulties in trying to find space in the curriculum and standards to fit in what they wanted to use from the workshop. This could be addressed by dedicating some workshop time to implementation issues, including potential barriers. Another way to avoid these problems is to plan workshops with strong links to science standards, which BSI has made an effort to do, and in the process to also raise teachers' awareness and understanding of the standards and their meaning.

To further address this principle, staff might consider:

- Making school administrators more aware of the professional development opportunities offered by the BSI, and working with specific school systems.
- Including a list of specific standards that are addressed in each activity or concept and more explicit relationships between them. This will allow teachers to better integrate the content with their curriculum and enable them to defend spending time on it. The state assessment frameworks should also be used in this respect, both to help teachers become familiar with the frameworks and to use the frameworks to "unpack" the standards.
- Providing teachers more explicit help in seeing the "big picture" of how a topic fits into the standards—for example, to understand that the *Blue Baby* case study is not about a particular, obscure disease, but a lesson that addresses life science standards on biogeochemical cycling, Earth science standards on human impacts on the environment, and inquiry standards.
- Beginning to integrate this and other BSI programs into a more comprehensive system at the university level that fosters and shares best practices in outreach to schools and teachers. As pressure on university faculty to do outreach increases (through funder requirements and university expectations), it is critical that those who have already developed expertise in this area contribute that expertise and their models to help improve the work of others.

7. Is continuously assessed.

The evaluation design for this study was informed by previous in-house evaluation work of the BSI, and their use of this formative feedback has enabled them to develop the skills and strategies needed to provide effective teacher workshops. Thus, good grounding was in place for the in-depth study reported here. The surveys summarized early in the report for these three workshops were designed to investigate the immediate reactions and short-term outcomes for

each of the BSI workshops. They were written in a form appropriate to the different types of workshops so that the results are comparable and may also be aggregated. While ratings were high, the surveys did reveal meaningful differences between workshops. Additionally, the participant interviews provided data on the longer-term impacts. The work of *Ethnography & Evaluation Research* as an independent research team strengthens the findings.

To continue to meet this principle, staff should consider:

- Continuing use of a standardized post-workshop survey with a common core set of questions. In addition to providing formative feedback for improving future offerings, this will provide a continuous and cumulative record that can be aggregated for summative feedback and enable better comparisons between workshops. Addition of specific topics can be done if individual facilitators desire, but core questions should not be omitted.
- Continue both formative and summative evaluation of all professional development offerings, both for individual programs and as a holistic program.

C. Concluding Remarks

To conclude, we note that "one-shot workshops" like those described in this study have been much maligned by teachers, researchers, and policy analysts (see references in Kennedy, 1999, p. 1). These critiques emphasize structural factors, recommending structural choices such as longer over shorter programs, group over individual work, program time interspersed with classroom time rather than separate, and teachers taking a role in defining and contributing to the content rather than passively receiving it. The one-shot workshop necessarily fails to meet many of these design criteria, and thus has been critiqued as a less effective type of professional development than more extensive, systemic efforts.

However, in her review of a small number of teacher professional development offerings (limited to those that provided direct evidence about student benefits), Mary Kennedy argues that this critique may focus too much on the *form* of teacher professional development in math and science and ignore the importance of program *content* as a predictor of benefit to students. In particular, she finds that "programs that focus on subject matter knowledge and on student learning of particular subject matter are likely to have larger positive benefits for student learning than programs that focus mainly on teaching behaviors" (Kennedy, 1999, p. 4). She hypothesizes that, when programs treat teachers as professionals who will apply their knowledge and insights to their work and provide teachers with better understanding of how students learn a particular subject, the teachers are enabled to "develop and refine" their own practices. That is, the structural features alone made no difference—though, she notes, when coupled with important content, they might indeed further enhance benefit to students.

The findings of the present study suggest that the TPD workshops offered by the BSI may fall into Kennedy's category of workshops that address the learning of particular scientific ideas—or very nearly so. The workshops clearly do focus on science content, and teachers reported important gains in knowledge and confidence as a result of this focus. The workshops also provide multiple examples of high-quality activities and materials, aligned with current research on inquiry learning, that enable teachers to take the content to the classroom, and a very high fraction of teachers do so. Clearly the teachers who participated feel engaged by the workshops

and valued by the program. They are treated as professionals who can make appropriate selection of workshop content and materials to use with their own students.

However, we have also suggested in this report that there is a subtle but noticeable absence of emphasis in the teacher interview data on student learning. Teachers mentioned that they like to include relevant and hands-on science because they know it appeals to their students, but they also express doubts on whether their students are capable of engaging in the level of thinking required by the workshop activities. Thus, the connection between the workshop content and student learning may not be as clear to the participants as necessary to truly improve classroom practice. Viewed as a group, then, the suggestions offered above may all be seen as ideas not for altering the focus of the workshops, but for strengthening and making more explicit the connection for teachers between their own new knowledge and classroom activities and student learning. Relatively modest adjustments to the workshops may help them to become not only high-quality "additive" professional learning experiences but "transformative" ones (Thompson and Zeuli, 1999).

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