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Bench to Bedside: The Effectiveness of a Professional Development Program Focused on Biomedical Sciences and Action Research

Abstract

A three-year, National Institutes of Health-funded residential project at a southeastern research university immersed 83 secondary science teachers in a summer institute called "Bench to Bedside." Teachers were provided with knowledge, skills, experiences, and incentives to improve their science teaching skills and increase their awareness of scientific processes, technologies, and careers through examination of the translational medicine continuum of basic to clinical research. This was done with the help of medical school researchers, clinical personnel, biotechnology entrepreneurs, program mentors, and participants from the previous year. A critical component of the institute was the preparation and implementation of an action research project that reflected teachers' newly acquired knowledge and skills. Action research proposals were critiqued by project team members and feedback was provided prior to action research implementation in schools during the following year. Teachers shared their action research with colleagues and the project team at a symposium and online as a critical step in networking the teachers. Results of a mixed methods program evaluation strategy, including data derived from open and closed survey items as well as program observations, indicate that the program produced significant gains in teachers' confidence to explain advanced biosciences topics, development of action research skills, and formation of a statewide biosciences network of key stakeholders.

Keywords: secondary science education; professional development; clinical and translational science; biotechnology

Introduction

As described in the Framework for K-12 Science Education (National Research Council, 2012), students need be prepared with knowledge, skills, and dispositions to enter a world and workforce characterized by the integration of the sciences, technology, and engineering. The biomedical sciences impact lives and careers in ways that support the aforementioned emphases for science education (Berk et al., 2014; Peterman, 2014). Science teachers need to be prepared and supported in their efforts to teach and mentor their students by experiencing relevant, intensive, ongoing professional development in the biosciences (Garet, Porter, Desimone, Birman, & Yoon, 2001; Leuhmann & Markowitz, 2007; Singer, Lotter, Feller, & Gates, 2011).

Biomedical Explorations: Bench to Bedside is a residential, secondary science teacher professional development program designed to create and expand partnerships that (1) connect researchers in interdisciplinary biomedical sciences and science education with teachers in under-resourced high schools in a southeastern U.S. state and (2) promote interest in and preparation for bioscience careers among students of the secondary science teachers. Described in this article are the design and evaluation of the first three years of this project.

Literature Review

Science Teacher Professional Development

Science teacher professional development is a complex process that requires elucidation of program goals prior to design (Brown, Bokor, Crippen, & Koroly, 2013). The process of science teacher professional development involves *interconnected* outcomes: enhancing teachers' knowledge, enhancing quality teaching, developing leadership capacity, and building professional learning *communities* (Loucks-Horsley, Stiles, Mundry, Love, & Hewson, 2010). Research shows that science teacher professional development programs that are on-going and job-embedded, or grounded in the practitioner's day-to-day teaching practice, improve science teachers' knowledge, skills, and dispositions (Basista & Matthews, 2002; Loucks-Horsley, et al. 2010; Luft, 2001). While many professional development models focus on implementation of pre-made curricula, some go further to support teachers in the development of their own instructional materials, thus empowering teachers and promoting sustainable change (Brown et al., 2013).

Teaching Biomedical Sciences

The National Institutes of Health (NIH) Common Fund places special emphasis on "bench-to-bedside" research, the translation of basic science research into practical clinical applications. A major source of federal funding for biomedical education programs comes from the NIH Science Education Partnership Award (SEPA), which encourages collaborations among educators, biomedical scientists, and community and industry leaders on projects that improve student understanding of the health sciences in K-12 education (www.nihsepa.org). While some science teacher professional development programs incorporate facets of medical research such as genomics (Munn, Skinner, Conn, Horsma, & Gregory, 1999) and bioethics (Chowning, Griswold, Kovarik, & Collins, 2012), few published studies focus on biomedicine in the context of translational research and incorporate the breadth of discovery science from the bench to the therapeutic product.

The study of translational biomedicine engages students of all ages in cutting-edge research and discovery by integrating scientific practices, cross-cutting concepts, and core disciplinary ideas - the three dimensions on which the science education standards are based (NRC, 2012). Given the limited funding and resources for K-12 science education, externally-funded programs have become increasingly important, helping to foster student achievement in and excitement about science, but also to expand and strengthen the pipeline of students choosing careers in science, technology, engineering, and mathematics (STEM) fields (Berk et al., 2014; Gervassi, Collins, & Britschgi, 2010; Winkleby et al., 2013). Preliminary reports of programs focused on biomedicine and/or biotechnology, which provide high school students with opportunities to engage in science and engineering practices, are encouraging as they document an increase in student interest and a positive shift in motivation to learn (Bigler & Hanegan, 2011; Santucci et al., 2004). Knowledge gains are reported, especially when teachers used active rather than passive teaching techniques (Mueller, Knobloch, & Orvis, 2009). Researchers describe active learning as "the implementation of a variety of specific student-centered instructional strategies to teach science," which may incorporate inquiry-based, hands-on activities (Taraban, Box, Myers, Pollard, & Bowen 2007). These gains are further enhanced through hands-on classes utilizing professional equipment (Bigler & Hanegan, 2011). Teaching biotechnology effectively can be accomplished by using activities based upon sound learning theories that include experiential approaches (Kolb & Kolb, 2005), inquiry-based learning (Taraban, Box, Myers, Pollard, & Bowen 2007), the use of computers or similar technology (Bitter, 2007), or even a multiple instructional strategy approach (Dunham, Wells, & White, 2002).

Scientist-Teacher Partnerships

In the context of teacher professional development, the teacher-scientist partnership model has emerged as a widespread, successful method to engage teachers in authentic content and scientific practices while also allowing for transferability to the classroom. Professional development activities that underlie partnerships between high school teachers and university faculty have significantly increased in recent years, a long-due response to the argument that these collaborations can help improve mastery of a particular subject (Beaudoin, Johnston, Jones, & Waggett, 2013). Drayton and Falk (2006) reported that the literature identifies five general approaches to the involvement of scientists in science education: (1) the scientist is a key member of the curriculum effort; (2) the scientist is a deliverer of content in teacher enhancement; (3) the scientist is a visitor to the classroom, or accessible to answer queries and seek resources; (4) the scientist is a partner with teachers and their students; (5) the scientist is a teacher mentor.

Action Research

Another form of professional development is action research, a reflective process of progressive problem solving led by individuals working on their own or as part of a community of practice to improve the way they address issues and solve problems (Mills, 2011). The action research process provides a means for teachers to reflect on their own practice and methods, but also serves a method for judging the success of professional development programs as it *is contextualized, systematic, localized, and aimed at developing changes in practice and student learning* (Mills, 2011; Wallace, 2000). Research suggests that teachers who engage in their own collective, self-reflective inquiry are likely to improve and understand their practice far more than those who do not (Barnes & Barnes, 2005; Boles & Troen, 1997; Goodlad, 1994; Kemmis & McTaggart, 1988). Factors surrounding action research and teacher leadership have been associated with improvement of "low-performing" schools: assistance, collaboration, data-driven decision making, leadership, assessment, and high expectations (Duke, 2006). Action research can be a valuable tool in these situations, particularly for educators trying to determine the causes for drops in student performance in order to intervene early. Failure to address student achievement problems can set in motion a dangerous descent in which each new dip triggers new problems and accelerates a school's rate of decline (Duke, 2006).

Theoretical Framework

The *Bench to Bedside Program* (B2B) is grounded in social-cultural theories of learning and motivation evolved from the work of Vygotsky (1978) and others (Liem, Walker, & McInerney, 2011), with focus on the social nature of learning in context. Novak (1998) holds that meaningful learning underlies constructive integration of thinking, feeling, and acting, leading to empowerment for commitment and responsibility. Constructivist learning theories have been advanced and further modified by researchers in past decades (Driver and Oldham, 1986; Novak, 1977; O'Loughlin, M., 1992, von Glaserfeld, 1992). Current sociocultural research ponders questions that investigate complex factors influencing human activity (Schoen, 2011). Learning occurs in communities characterized by cognitive socialization in which individuals learn requisite skills to function as valid, collaborative community members able to communicate via accepted patterns of discourse (Brown, Collins, & Duguid, 1989; Sainsbury & Walker, 2011). Keeping in line with the aforementioned ideas of situated cognition and social learning theories, the program embeds learning in activity and makes deliberate use of social and physical contexts. The overall intent of B2B is to provide a framework for contextual, constructivist, collaborative experiences in biomedical sciences for secondary school science teachers as they are immersed in authentic discovery-based research, culminating in a viable network of teachers, scientists, and science educators focused on student learning.

Program Design

Goals and Aims

The main goal of B2B is to create and expand partnerships that connect high school teachers with researchers in interdisciplinary biomedical sciences to promote students' interest in and preparation for bioscience careers. This innovative program involved three cohorts of high school teachers (83 total participants) in a two-week, residential summer institute with follow-up classroom action research during the school year. Situated within an education and training center at a southeastern research university, B2B provided an experimental sequence in basic science and clinical and applied research environments that illustrated scientific content, pedagogical methods, action research processes, and career options. B2B utilized a teacher-scientist partnership model for professional development, bridging the gap between secondary and post-secondary education and encouraging ongoing communication among members of these groups in order to create sustainable learning communities that maximize student learning. The program was designed and evaluated around three primary aims:

Aim 1: provide teachers with knowledge, skills, experiences, and incentives to improve science education and increase awareness of scientific processes, technologies, and careers examining the translational medicine continuum of basic to clinical research and to the development of clinical therapeutics;

Aim 2: assist teachers with the a) development of action research proposals based on biotechnology and biomedical concepts investigated during the summer institute and b) implementation of the proposals in their classrooms during the following school year;

Aim 3: create a network of science educators among secondary teachers, higher education faculty/staff/students, and industry partners.

Program Description

The program began with an intensive two-week (~80 hour) residential summer institute that employed inquiry-oriented approaches to content, labs, and activities that illustrate the process of translational medicine (taking a therapy or device from the lab "bench" to a clinical setting "bedside"). The institute was designed to deepen educators' content knowledge in the discoveries and applications of translational medicine while providing training in biotechnology skills. Program staff, university faculty, College of Medicine graduate students, and private sector entrepreneurs, shared their expertise with program participants in a variety of ways. Activities included interactive lectures, hands-on laboratory experiments and activities, and research and clinical laboratory tours—all designed to expand content knowledge and correct common misconceptions within medical research. University researchers offered content guidance as needed, while teachers designed new lessons to translate this content into their classrooms. In the latter two years of the program, alumni from previous cohorts were invited back to speak to the new cohort about their experiences in implementing their own action research proposals.

Figure 1a summarizes the flow of the two-week program. The focus of week one was discovery-based research (including laboratory activities such as recombinant DNA technology and gene diagnostic techniques), faculty presentations, and research laboratory visits. Week two continued the translational research process—exploring clinical trials, manufacturing and process design, and hands-on activities involving quality control of products using protein and antibody analyses—and a visit to an off-site biotechnology hub, including both start-up and established industrial programs. Throughout the institute, teachers learned the various aspects of action research and designed action research proposals.

At the close of the summer institute, teachers presented their action research proposals to their peers, explaining how they intended to integrate program content into their courses in the upcoming school year. After modification based upon feedback from peers, program staff, and faculty, teachers were eligible for a mini-grant to implement their proposals in their classrooms. Teachers were also eligible to participate in an equipment locker-lending program, allowing for a short-term loan of the equipment and supplies necessary to implement the action proposal. Furthermore, teachers could request to have a B2B scientist or staff member visit their classrooms to give an interactive presentation on related content or careers in bioscience as a supplement to the activity outlined in the teachers' action proposals.

Early the next year, teachers returned to campus as part of a three-day science symposium to present their action research interventions and outcomes to peers and the B2B project team. Teachers who successfully completed all program components, including implementation and submission of a written report detailing student outcomes, were awarded three graduate credits through their choice of the College of Medicine or College of Education. Figure 1b shows teacher progression through one full year of the program.

Participants

Up to 30 teachers per year were invited to attend the B2B institute after a competitive application process. Qualified applicants were experienced secondary science teachers, the majority having at least five years of teaching experience in their discipline. Admissions favored teachers coming from economically disadvantaged schools (based on the percentage of students eligible for Free or Reduced Lunch). Three cohorts of teachers, 83 teachers from 32 counties across the state, completed the B2B program. Participant demographic information is outlined in Table 1.

Project Team

The B2B team consisted of a program director (a professor of biochemistry in the College of Medicine); two program

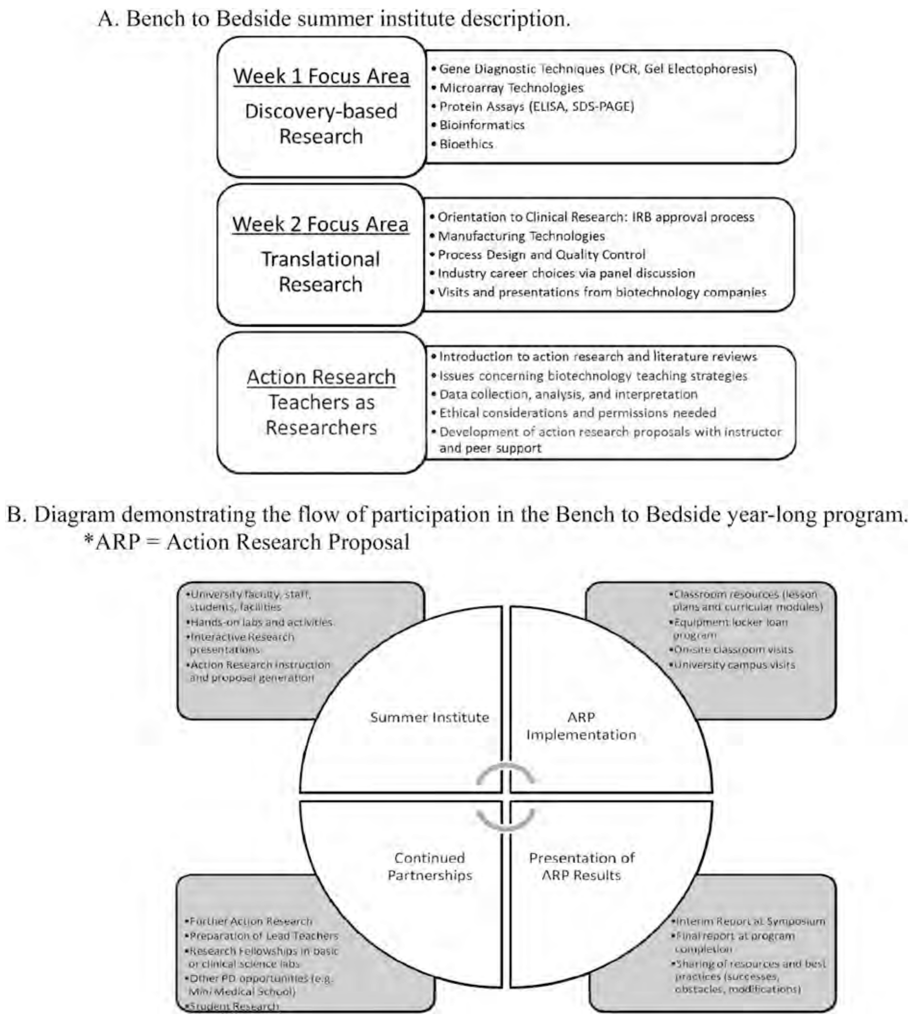

Figure 1. A. Bench to Bedside summer institute description.

coordinators, one specializing in biomedical science content and the other specializing in STEM education; two action research facilitators, science educators with considerable experience in teaching action research courses / workshops and in program evaluation; and the evaluation team, including the Director of the Office of Program Evaluation and Student Assessment, as well as the two action research facilitators. The project team met prior to the institute, regularly during and after each summer session, and after each action research project sharing session at the science symposium, facilitating continual review, monitoring, and revision of the program sequence, content, pacing, and evaluation strategies.

Action Research

Instruction on how to conduct action research was integrated into the two-week institute and included discussion, activities, and feedback. Focus areas included the reflective and cyclical nature of action research (Mills, 2011), formulating research questions, accessing electronic databases, writing literature reviews, designing interventions and assessments, sharing best teaching practices, and developing action research proposals around biomedical concepts integrated into science curricula. Teachers received multiple handouts with background information that stimulated discussions. In-class mentoring and dialogue assisted teachers in developing and refining their research questions, as well as navigating electronic databases to find literature to incorporate into their literature reviews. Some expressed concern about the "scientific" nature of action research, as it does not include control groups or multiple modes of assessment. Their comfort level was increased when they explored some of the limitations of traditional scientific quantitative research designs. They grew to appreciate the unique interactions with their students and fellow teachers, as well as issues involved in classroom-based research, and the appropriateness of including qualitative strategies to investigate their students' learning needs.

Teachers developed individual action research proposals in order to integrate B2B content and skills into their classrooms and assess students' learning, interest, attitude, and behaviors. They were provided with a proposal template (Figure 2) and shown proposals from previous cohorts (initial group looked at sample proposals). After the institute action research proposal drafts were submitted electronically, critiqued, modified, and returned as final proposals by the teachers. Final project reports were submitted at end of school year.

Research Design

The philosophy undergirding the entire study was one of an ongoing action research endeavor, resulting in alterations to the program as it progressed (Gay, Mills, & Airasian, 2009). Thus, the challenge was to collect data that could be analyzed consistently over the duration of the project while immersing teachers in optimal experiences.

This study used a mixed methods design, gathering both qualitative and quantitative data concurrently, to better evaluate the degree to which the three program aims were achieved. This approach combines supportive and contradictory evidence gathered by each method, using triangulation to offset concerns about ecological validity and generalizability (Creswell, 2008; Gay et al., 2009; McMillan & Schumacher, 2010).

Qualitative Data

Qualitative data were acquired through open-ended survey items, observations

Table 1. Demographic Information for Three Cohorts of B2B Participants

	Frequency (#)	Percentage (%)
Gender		
Male	14	17
Female	69	83
Race		
African American	11	13
Asian	1	1
Hispanic	8	10
Pacific Islander	3	4
White	60	72
Education		
Bachelors, Education	10	12
Bachelors, Math	4	5
Bachelors, Science	67	81
Advanced Degree (M.S./PhD)	49	59

during the institute and classroom implementation, project team meeting notes, and analysis of action research proposals and research reports. Open-ended survey items included reactions to the components of the program and suggestions for improvement. These data were analyzed through a constant comparison procedure of coding and emergence of categories grounded in data to explicate teacher experiences and social processes within the institute and afterward (Bogdan & Biklen, 2007; Creswell, 2008).

Evaluation of short-term intensive intervention programs can be problematic, as evaluators often rely on self-report measures and pretest-posttest designs to measure perceived change (Moore & Tananis, 2009; Pratt, McGuigan, & Katsev, 2000). Response shift bias can occur when a respondent's frame of reference or evaluation standard changes significantly during the course of an educational intervention, compromising the validity of the pre-post rating comparisons. If participants are unfamiliar with terms and concepts needed to answer pretest questions, they may be unable to accurately judge baseline knowledge or skills (Allen & Nimon, 2007). The *retrospective pretest* (RPT) has been proposed as one solution to the presence of

Bench to Bedside: Professional Development Program

Introduction: With school reform comes recognition of the importance of teacher empowerment in changing school culture and classroom teaching. Action research is a catalyst for collegial problem-solving and professional growth. Action research is an excellent methodology for *using inquiry* to study teaching practice, student-teacher interactions, and student learning, providing teachers with the tools, philosophy, and practice that allow them to systematically study the effects of their teaching on student learning. Action research is an ongoing source of teacher professional development. **In the Bench to Bedside Summer Institute, the Action Research Proposal is a critical part of the documentation of Action Research planning for the program staff and the funding agency. The proposal is the foundation for the Action Research project.**

The **action research proposal** must be word-processed and must include the following :

Title: Develop a title page with your name, position, correspondence information, and descriptive title of your action research project; use it as a cover sheet for your **action research proposal**.
Abstract: The abstract should summarize your action research purpose and methods. It should have a 150 word limit.
Rationale: This section should describe your "story", i.e., your particular area of action research emphasis and your reasons for choosing it. These reasons should be based on your own experience, the learning needs of your students, and your review of pertinent literature related to biomedical sciences teaching and learning. You need to include at least *three* references; you may use articles, books, relevant websites, etc. Library databases and Google Scholar are good starting points. This section should end with your research "area of focus" statement, which includes an intervention and its impacts on students. (You will collect data to determine these impacts on student achievement, interests, attitudes, etc.)
Action research intervention: Describe the intervention (teaching strategy or innovation) that you are implementing and the biomedical sciences content and skills that it encompasses. Also, provide background on your teaching context (Whom are you studying and when?) You may develop a unit, module, or other creative approaches to implementation.
Connections to Bench to Bedside summer institute: Describe the specific UF Bench to Bedside Institute connections.
Data collection and analysis: Develop and describe a data collection plan that links to your research purpose. Describe data analysis and interpretation plans.
Literature cited: Include a reference list of all pertinent print and/or digital resources that you used in your rationale or will use in your implementation of your action research project.
Budget and budget justification: List and describe necessary resources and costs.
Permissions: Describe any permissions that you need to implement your action research project (principal, parents, etc.)

Figure 2. Bench to Bedside Action Proposal Template.

response shift bias (Campbell & Stanley, 1963; Howard, 1980).

In the RPT design, the pretest is administered at the same time as the posttest and participants assess both their new level of understanding or skill and reflectively assess their pre-participation level of understanding or skill. A single evaluation of both retrospective pre and post-program ratings administered at the end of the program is simple and less time consuming. In addition, completing retrospective ratings with the post-program evaluation provides participants with an opportunity to reflect on how much they have learned during the summer institute, something we were interested in promoting. The use of RPT is becoming more common in the evaluation of professional development programs in science education.

The RPT approach is a departure from traditional methodological logic since both pre and post data are collected following an intervention. As such, researchers are generally cautious about retrospective ratings, because they can be perceived as less rigorous due to certain noteworthy shortcomings**.** The major criticism of the retrospective pretest/posttest design is that, although it does reduce response-shift bias, other sources of bias may be introduced. It is possible that participants will demonstrate learning gains (or attitudinal change) in an effort to make the researchers or sponsors of a training program "look good" regardless of whether learning actually took place (Hill & Betz, 2005). It has also been suggested that there is the possibility of social desirability bias (tendency of survey respondents to answer questions in a manner that will be viewed favorably by others), acquiescence bias (the tendency for an individual to agree or respond positively without regard to the question asked), impression management (active self-presentation of to enhance a person's image in the eyes of others) and effort justification (the tendency to attribute a greater value to an outcome that requires effort to achieving) when retrospective pretest self-report questionnaires are used, but this is true for both the traditional pretest/posttest and retrospective pretest/posttest designs. Inaccurate memory recall can also pose a threat to validity when using the RPT method (Hill & Betz, 2005).

The program being evaluated and the goals of the evaluation should drive the decision of which type of pretest to use. Cantrell (2003) measured science teaching efficacy beliefs of pre-service teachers and concluded that RPTs may produce gain scores with greater validity and greater statistical power. An investigation by Howard et al. (1981) demonstrated that retrospective pretest-posttest self-reports actually diminished the effects of social desirability bias in participant responses. Ulmer et al. (2013) used the RPT with a second posttest nine months later to examine impact of a summer institute on science teaching self-efficacy. Hill and Betz (2005) recommended the use of RPT for assessment of individual perception of change and concluded "if the aim is to understand how participants feel about program effectiveness and their personal growth or skill acquisition, the retrospective pretest provides a more direct assessment of these factors" (p 514). When the goals of the evaluation are to have program participants describe their perceived change or how they feel about the program, retrospective ratings provide the best option. If the goal is to benchmark against other programs, traditional pretest ratings are best, as they are still the most commonly used.

The Bench to Bedside program was designed to introduce participants to advanced level topics in the biomedical sciences and to the methodology and practice of action research. Since the participating teachers were unlikely to be sufficiently familiar with these content areas and concepts prior to their summer institute participation, the evaluation of B2B outcomes used an RPT to gauge the effects of the program on the participating teachers' perceived confidence to explain the biomedical science topics, covered during the summer institute, to another science professional reasoning that doing so would require a deeper level of understanding. Although confidence and self-efficacy are not synonymous, a high level of perceived knowledge is associated with high self-efficacy, and self-efficacy has been positively related to a teacher's intent to adopt new innovations (Smylie, 1988). Evaluation items that assessed program components and processes related to action research (no pre-program ratings) and open-ended questions were also included. Beginning with the second cohort, the surveys were re-administered six months after the conclusion of the summer institute.

Quantitative Data & Analysis

Quantitative data were analyzed using IBM SPSS Version 22.0 to compute descriptive statistics for evaluation items. Retrospective pre-post differences were tested with two-tailed dependent sample (paired) t-tests, with the significance level set at $\alpha = .05$. In order to justify using the average rating on the confidence items as a summary measure, intraclass correlation coefficients (ICCs) and the 95% confidence intervals were calculated. The ICC is interpreted as the proportion of relevant variance that is associated with differences among measured objects or persons (McGraw & Wong, 1996). The ICC is a point estimate that measures the reliability of measurements or ratings; the confidence interval describes the uncertainty inherent in this estimate, and gives a range of values within which we can be reasonably sure that the true effect actually lies. Common examples of ICCs in the literature are Cronbach's coefficient alpha and generalizability/dependability indices that arise from generalizability theory (Cronbach, Glaser, Nanda & Rajaratnam, 1972). Shrout and Fleiss (1979) describe the models associated with various intraclass correlation coefficients and McGraw and Wong (1996) provide procedures for calculating confidence intervals and conducting significance testing on ICCs included in SPSS. The form of the intraclass correlation coefficient depends on the experimental design and the conceptual intent of the study (Shrout & Fleiss, 1979). Since we assumed that the topics may differ in their difficulty**,** we used a two-way random model with measures of consistency. For each case, SPSS provides two

ICC estimates: one for the reliability of a single rating, and one for the reliability of the mean rating. In general, combining multiple ratings produces more reliable measurements. Results for the ICC (2,k) results are reported in the findings section (p.21).

Findings

Qualitative and quantitative findings are presented the three program aims, (1) biosciences content and process, (2) action research content and process, and (3) networking. Coding of written, narrative teacher feedback gathered from each cohort, evaluator observations during the institute as well as during classroom implementation, team meeting notes, and action research proposals resulted in 20 codes, which coalesced into three major themes: Reaction to Program, Learnings/Behaviors within Program, and Impact on Teachers and Their Students. The codes and their relevance to these three themes are summarized in Table 2. Aims 1 (biosciences content and process) and 2 (action research content and process) allow for the discussion of the themes that emerged from this qualitative analysis, and supporting examples taken from participant feedback are provided within each section**.**

Aim 1: Biosciences Content and Process

Theme 1: Receptivity to Program. Overall, teachers perceived a need for the B2B content and were open to immersion in B2B lecture and laboratory experiences, expressing appreciation for the expertise and dedication of the biomedical scientists with whom they interacted. Positive reactions ranged from effusive:

If a teacher wants to grow and …wants access to the quickly developing world of biotechnology with an unbelievable support system of supplies, staff, researchers, and opportunities, then …the Bench to Bedside program is for you.

to reflective:

Guest lecturers are so valuable; variety is A+ and usability is A+. "Checking" on us and "how's it going" … makes me feel welcome…

However, some important issues of program time management, program pacing, and variation in the disciplinary background of participating teachers. For example, one teacher wrote:

…there were times when we weren't given sufficient time to digest or process some of the content presented.

Another teacher noted:

Maybe more free time in the evening.

The varying backgrounds of the teachers resulted in suggestions such as the following:

Explain process-reasons for procedure, this was done and much appreciated – but some people without necessary background may not understand all.

I feel a lot of (institute) science is geared toward biology…and since I teach chemistry, I have to adapt most of the labs. The level of my students is not high enough to understand most of the chemistry in biotechnology at this time.

Theme 2: Learnings within Program. The majority of participants perceived and demonstrated significant learning gains, supported by both qualitative and quantitative data. Several teachers mentioned specific areas of learning, e.g., gene therapy, stem cells, viral vectors, glycogen storage disease, clinical trials, protein crystallization:

The hands-on lab training and experiences assisted in my understanding of the skills needed in the biotechnology field.

I have learned so much…gained confidence with lab procedures. Knowledge about the science involved in the research…

…the diversity of scientific disciplines and the availability of career opportunities in science.

Theme 3: Impacts on Teachers and Their Students. Teachers provided detail on the impact of B2B on themselves, focusing on collegial relationships and personal development:

Perhaps more important than …new technologies and lab experiences …was the opportunity to form a lasting network of teachers and professors for continuing support and collaboration.

B2B afforded me the opportunity to stay abreast of current research and developments in science… and to interact with those investigators at the forefront of their field.

The teachers' comments provided insight into ways that their new content knowledge might catalyze more robust experiences for their students:

The program provided many ideas to create an interactive, inquiry experience to further draw the interest of my students.

My students have definitely benefitted from my participation in the program because they in turn have become familiar with the latest research in medicine.

Table 2. Summary of code clusters and their respective major themes resulting from qualitative analysis

Theme 1: Receptivity to Program	Theme 2: Learning and Behaviors within Program	Theme 3: Impact on Teachers and Students
Teacher background and circumstances	Inquiry-oriented biosciences learning	Congruence with school curricula
Relevance to teachers and their students	Previous action research skills and experiences	Interactions with colleagues, project team, scientists
Management of institute requirements	Action research process	Available resources
Technology literacy and accessibility	Classroom assessment concerns	Barriers to implementation
Project team planning & communication	Action research proposal feedback	Value-added outcomes
Project team and scientists' expertise & commitment	Biomedical sciences career awareness	Post-program outreach
Teacher affect		
Time & pacing issues		

I was compelled to persuade my administration to offer an honors genetics class to provide more upper level learning experiences to my students.

…helped so much for us to bridge the gap of what our high school grads do and what they should be doing.

…I am better able to help students to craft their research questions and guide them to resources.

Aim 1 Quantitative Findings

All three B2B cohorts completed an evaluation using RPT at the end of the summer institute. For each topic, participants rated their confidence "to discuss with and explain this concept to another teacher or science professional" on a 10 point, behaviorally anchored scale where 1 = no confidence at all and 10 = completely confident. Participants were instructed to provide confidence ratings for each topic, one for "today", i.e., at the end of the B2B summer institute, and a pre-institute rating, i.e., before the B2B summer institute. Table 3 reports descriptive statistics for retrospective pre-post confidence ratings for the topics that were consistent for all three cohorts (N=76). In addition to the mean and the standard deviation, we report the 95% confidence interval for the mean and the effect size associated with the mean difference measured by Cohen's d, i.e., the standardized mean difference for paired samples. Effect sizes were large (Cohen, 1988), ranging from 1.28 to 7.86. In all topics areas, dependent samples (paired) t-tests yielded evidence of significant pre-post differences ($p < .0001$).

The average confidence ratings were calculated to provide a general measure of confidence to explain advanced topics in biomedical sciences. For both retrospective pretest (N=77) and posttest (N=76), ICC = .95 with 95% confidence interval (.93, .96). The pre-program mean confidence rating over all topics was 3.86, the mean confidence rating on the last day of the program was 7.56, the mean gain score was 3.70, and the mean effect size was 1.65. Participants felt most confident explaining the genetics of disease at both pretest and posttest (5.82 vs. 8.45); they were least confident in their knowledge of glycogen storage disease when they began B2B, but experienced the largest increase in confidence to discuss this topic immediately following participation in the program (difference = 5.92, d = 2.59).

Following the first cohort, the evaluation team realized that the teachers' mid-year return to campus provided an opportunity for longitudinal study of the impact of the program on the participants. Therefore, for cohorts 2 and 3, data collection occurred in two phases. The retrospective pre-post assessment was administered on the final day of the summer institute with the second administration approximately six months later after the teachers had returned to the university to present their action research projects. For the subset of data for which we had complete confidence ratings at all three points in time (N = 31), ICC = .95 (.92, .97). Multivariate analysis of

Table 3. Retrospective Pre-Post Confidence Ratings[1] (All cohorts, N = 76)

Topic	Before Bench to Bedside (Retrospective Pre Test) M	SD	After Bench to Bedside (PostTest1) M	SD	Difference (Post - Pre)	Effect Size (d)[2]	t[3]
Biomedical research (human subjects)	4.33	2.67	8.06	1.69	3.73	1.64	14.5
Clinical research	3.76	2.45	7.92	1.78	4.16	7.86	16.5
Crystallization	3.04	2.35	6.83	2.02	3.79	1.63	14.3
Drug Development	3.67	2.20	7.63	1.62	3.96	1.95	17.3
Enzyme-linked immuno-sorbent assay (ELISA)	3.88	2.82	6.69	2.18	2.81	1.32	11.7
Gene cloning	4.55	2.66	7.73	1.67	3.18	1.54	13.6
Gene therapy	5.82	2.71	8.45	1.39	2.63	1.23	10.8
Genetic screening	5.06	2.80	7.88	1.80	2.82	1.34	11.9
Genetics of disease	4.56	2.71	7.86	1.30	3.30	1.28	11.3
Glycogen Storage Disease	2.09	1.77	8.01	1.68	5.92	2.59	22.9
Microarrays	3.18	2.45	6.96	2.04	3.78	1.62	14.2
Protein purification	3.17	2.39	6.79	2.09	3.62	1.56	13.8
Translational research	3.10	2.37	7.47	2.04	4.37	1.91	16.9
Average confidence (all topics)	3.88	1.97	7.56	1.47	3.68	2.04	19.8

[1] The scale for these confidence items was a 10-point scale with the end-points anchored with the following descriptors:
1 = No confidence at all to discuss and explain the concept to another teacher/professional
10 = I feel completely confident to discuss with and explain the concept to another teacher/professional
[2] Cohen's d, the standardized mean pre-post difference, was computed to measure effect size
[3] The dependent samples t-tests for pre-post differences were all significant ($p < 0.0001$)

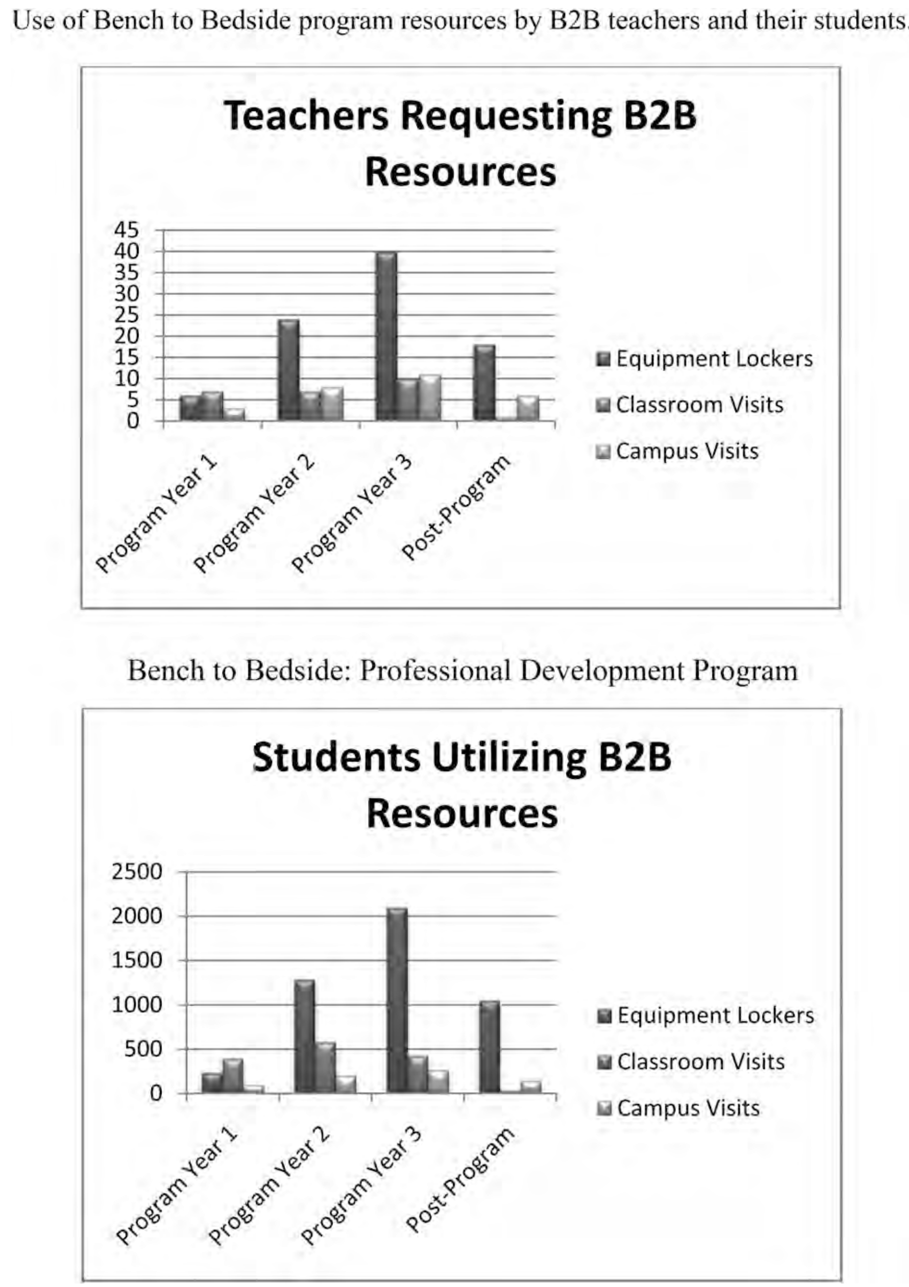

Figure 3. Use of Bench to Bedside program resources by B2B teachers and their students.

variance (MANOVA) was used to test the effect of repeated measures of average confidence over time. There was a significant effect for time, $F_{2,29} = 70.12$, $p < .0001$. Post hoc contrasts found that average confidence scores at posttest1 (M= 7.94) and posttest2 (M=7.66) were significantly higher ($p < .0001$) than the average score on the retrospective pretest (M=4,63). There was no difference in average confidence measured at the end of the summer institute, posttest1, and average confidence ratings six months later (7.94 vs. 7.66), $p = .20$. This suggests that teachers gave themselves high ratings for their confidence to discuss complex biomedical topics after their summer experience and gains in confidence are robust.

Multiple incentives were provided to the teachers in order to assist them in transferring their new content knowledge, as well as to aid in the implementation of more inquiry-based labs and activities. The curricular materials and best practices developed through B2B on clinical/translational research have all been made available on the web for download. 62% of program participants have requested an equipment locker and 27% have requested multiple lockers. Two years after the completion of the final cohort, 20% are still actively requesting lockers. Seven hundred secondary students have visited the university campus with their teachers to perform biotechnology experiments in an authentic environment and to interact with graduate students and faculty. Figure 3 demonstrates the use of program resources by B2B teachers and their students throughout the three years of the program (2010-2012), and post program (2013-2014). In addition, B2B program activities have been used at a number of science festivals, content clinics, and workshops. To date, we estimate that B2B program activities have been successfully implemented with 10,000+ students.

Aim 2: Action Research Content and Process

Theme 1: Receptivity to Action Research. Teachers acknowledged the benefits of action research as follows:

The process of action research made me think about my own teaching in ways that I had never done before.

I found it effective. It is stressful to have a draft by the end of the workshop… But I also understand that this ensures better success in writing the proposals and following through with it. It also helps to have experts that we can ask questions.

I feel we spent the right amount of time working on our Action Research project…I was not overwhelmed one day with all the information. I like how it was spread out…having the time to work independently was very helpful.

However, the compressed time period and overall demands of the institute, ongoing necessity for technological support to complete the proposals, and the variation in previous exposure to action research practices resulted in comments such as the following:

Allow more computer time with internet access

(need) more cohesive step-by-step template to follow (first year comment)

Please separate those who do not know how to spend time in researching and writing from those of us who do and let us go on our own.

With so much new content during the institute, it is difficult to focus on the details of action research protocol.

Cohort 1 participants did not respond positively to a textbook on action research and this was subsequently replaced with selected handouts. In addition, the proposal template was refined based on Cohort 1 input. Evaluator observations and teacher input led to a change in placement of action research content to earlier in the day's agenda for cohorts 2 and 3, as fatigue appeared to be a factor affecting receptivity to learning about action research.

Theme 2: Action Research Understanding. The benefits of learning about and doing action research were notable, especially with respect to identifying and meeting the learning needs of students:

I learned a great deal in performing this action research project, spanning from how my students learn to the level of patience it takes to teach a slightly clumsy seventeen year-old boy the difference between the first and second stop of a pipette.

I now can link specific reasons as to why this lesson should be taught and its benefit to students. The project also allowed me to specifically focus on the needs of each student and how they learned. I was afforded the opportunity to work individually with students.

This process showed me that I can step outside the box to try something new. … Implementing this action research allowed me to have better discussions with my students. This topic was carried on throughout the entire year.

The collegial nature of ongoing action research was well-articulated by one teacher, expressing the sentiments of many:

I learned and applied action research and I made connections to professionals that I will continue to utilize as part of my teaching.

Further information and support related to data gathering and analysis was requested by several teachers and reinforced by observers as they reviewed proposals and critiqued mid-term action research presentations:

I learned that there is not enough time during the semester to adequately analyze student progress throughout the semester/unit. I appreciate the formality of the presentation of the data; however, I would suggest more hands on assistance from (the facilitators) in the development of the assessment tools and the analysis of that data.

More information and examples related to the data requirements of action research were infused into the program after year 1. Gains are evident in Table 4, which displays sample *Teacher Action Research Projects: Title, Focus, Findings,* representative samples from the 3 cohorts. The action research proposals, submitted by all 83 teachers, covered principles of biotechnology, translational medicine, DNA technologies, and scientific career choices, among others, and employed various teaching and assessment strategies. Despite the fact that participating in the midterm symposium meant time away from their classrooms, 58/83 (70%) teachers were able to attend and share their action research projects with their program peers. Those who could not attend were asked to submit their report electronically.

A written report was submitted by 69 of the 83 total participants (83%) in the spring of their program year, providing data on student outcomes as a result of their classroom intervention. Of those who did not submit a report, several cited legitimate reasons for their inability to complete the program, such as changes to course subject and teaching load (4), district/state interventions at their schools (2), debilitating health problems (2), and leaving the teaching profession (2). In addition, there were four who were not located despite repeated attempts at contact.

Theme 3: Action Research Impacts on Teachers and Students. Several teachers commented on the utility of their biomedical science-focused action research experience and its effects on themselves and their students. The teachers used action research inquiry processes to make classroom decisions and to stimulate students in their own inquiries:

Student achievement and interest in science increased based on the data collected …

The implementation of my action research proposal has allowed students to be exposed to cutting edge technologies that would not have been possible had it not been for (this program), their staff, and equipment lockers.

The action research process helped me to become more observant and analytical of the teaching strategies and the results … as far as student success was concerned. I have become more conscientious about monitoring the manner in which content is delivered and have even mastered the art of being flexible in making on the spot adjustments to a lessons as needed if I observe that students are having difficulty with the content or the context in which the material is being delivered. I am looking forward to doing more action research for the upcoming school year and since this was my first round, I am anticipating that I will be able to refine my methods of collecting data …

However, impacts can be diminished by the realities of actual school environments in which time is a factor and teaching assignments and curricula change:

I learned it is difficult to accomplish a piece of action research if you cannot control most of the environment you are working in.

I have had to limit the project due to time constraints.

I had to change my research subjects from physical science students to biology students.

Aim 2 Quantitative Findings

Quantitative data related to action research processes were collected on

Table 4. Sample Teacher Action Research Projects Title, Focus, Findings

Title	Focus	Findings
A Comparative Study of Teaching Strategies in Biotechnology Education With the Inclusion of Game Simulation	Effect of 4 week biotech unit in Chemistry and Physical Science Classes; used senior students to mentor game	-All classes increased in biotech content knowledge -Biotech game more effective with chemistry students; others had concept attainment difficulty
Teaching Lessons in Bioethics in a Biotechnology Class	2 week exposure to bioethics via lecture, case studies, and class discussions	-Emotionally charged information retained better - Demonstrates need for integration of bioethics throughout courses rather than intense treatment
High School Physical Science Students' Ability to Identify Biotechnology Careers via Student Career Research and Sharing	Impact of biotech career unit focused on student research and technology integration on biotech career identification	-56% increase in biotech career identification based on pre and post assessments -Recommend use in biology classes and middle school science
The Effect of Case Studies and Biotechnology Laboratory Techniques on the Confidence, Problem Solving Skills and Science Career Interest of Minority and Female Students	Use of case studies to expose minority and female students to STEM careers in anatomy and physiology classes	-Surveys and discussions indicated that knowledge and attitudes were enhanced -Will continue discussions and administer final survey
Improving Scientific Research & Experiment Skills	Use of biotechnology to enhance the internet research, experimental skills, and writing skills of high school science research students	-Increased the number of students researching biotechnology -Used a rubric for group article critiques -Good improvement on 2000 word research paper – better written with more science; teacher used comprehensive rubric
A Study of the Impact of Translational Medical Research and Biotechnology Laboratory Applications on Student Understanding of Biomolecules and Attitudes toward Stem Cell Practices	Addition of translational research activities in dual enrollment biology classes	-Teacher journal showed that students are100% engaged -7/9 of students increased attitudes – more positive -Students showed gains on knowledge test -Students responded more seriously to knowledge test rather than attitude assessment -Teacher will make changes based on findings, e.g., introducing applications earlier
The Effects of Biotechnology Based Case Studies Combined with Biotechnology Laboratory Experiences on Student Interest and Knowledge/Skills in an Advanced Placement Environmental Science Class	Promoted interest using biotechnology labs and case studies in AP Environmental Science students, many of whom are level 1 and 2 readers	- Unit Test, On task Checklist, Interest Survey Unit test scores increased 24%, with free response items up 74%. -66% more on-task behavior and 88% increase in interest -
A Study of the Effect of inquiry Based labs, Using a Biotechnology Model, on the Attitudes and Performances of Students in an Alternative School Setting	Employed short, content-focused lessons and supporting discovery labs to teach biotechnology in an alternative setting	-Pre and post knowledge and attitude assessments -70% of students showed some knowledge improvement -Peer pressure seemed to impede students' admitting of attitude change toward science
A Study of The Effect of Teaching a Unit About Translational Research on Student Interest in Pursuing Careers in Biomedical Science	Infused lessons focused on stem cells and biotechnology careers into an Anatomy and Physiology class	-Pre and post surveys of knowledge and career interest -Stem cell Knowledge increased -More interest in biotechnology and medical doctor careers

the evaluation surveys. Feedback from teachers, both qualitative and quantitative, was used to modify and improve components of the program. Analysis of a checklist after the first year led to the design of survey items around action research processes. Process items questions were scaled from 1 (strongly disagree) to 6 (strongly agree). Results are reported for cohorts 2 and 3 in Table 5 and reflect teacher perceptions immediately after the program and upon their return to campus to share their action research 6 months later. For each process item, the percentage of respondents who agreed or strongly agreed with each statement are reported. Some questions were asked only at the end of the summer institute or on the midterm evaluation. Differences in planning and executing an action research project are evident in the data, where midterm perceptions (~6 months post summer institute) are mostly lower than those at institute's end. Noteworthy are the large percentages of teachers who planned to stay in touch with institute staff and resources and to use institute content learnings in classroom lesson planning. Perceptions of sufficient action research mentoring remained high in Cohort 2 and increased in Cohort 3. Insights into responses are provided in the qualitative data discussion by theme that follows.

Aim 3: Networking

Teachers commented on the importance of networking:

…opportunity to form a lasting network of teachers and professors for continuing support and collaboration. (often cited)

Working with peers and university staff to develop new, cutting edge curricula.

Networks were generated and/or strengthened by teachers' sharing of their own best instructional practices during

Table 5. Action Research Process Items

	Cohort 2 (2011-2012)		Cohort 3 (2012-2013)	
	Summer Program End	Midterm	Summer Program End	Midterm
	(n = 28)	(n = 19)	(n = 25)	(n = 20)
Question	% Agree	% Agree	% Agree	% Agree
I feel well-prepared to conduct a formal Action Research Project.	96.5	89.5	76.0	70.0
I am prepared to do the self-reflection necessary for successful Action Research.	100.0	84.2	76.0	65.0
I was able to conduct an adequate review of the literature for my project.	67.9	84.2	64.0	65.0
I had adequate access to on-line databases to support my literature review.	59.2		80.0	
I had sufficient time to search on-line databases to support my literature review.	35.8		44.0	
The textbook was useful in preparing my action research proposal.	37.0			
Handouts were useful in preparing my action research proposal.			68.0	
I was able to describe my action research intervention in detail.	75.0		48.0	
I was able to include relevant biomedical science content in my action proposal.	85.7	89.5	88.0	60.0
I included multiple data collection strategies in my action research proposal.	96.3	84.2	84.0	55.0
I am confident I will be able to analyze the data I collect.	96.4	83.3	76.0	52.6
I received sufficient mentoring in the development of my action research project.	96.4	89.4	58.3	70.0
I plan to share the outcome(s) of my action research with my colleagues.	89.3	79.0	96.0	65.0
I plan to stay connected to CPET and its resources (e.g.,programs, websites, activities).		100.0		85.0
I plan to conduct further action research.		73.7		45.0
I will plan lessons using the knowledge and skills learned during Bench-to-Bedside.	96.4	89.5	92.0	90.0
I have the knowledge and skills to find additional resources to teach biomedical sciences to my students.	96.5	78.9	96.0	80.0
I will share my Bench-to-Bedside knowledge and skills with colleagues (in my school/district).	96.5	68.4	96.0	70.0
I will seek further opportunities to learn about biomedical research applications.	100.0	79.0	80.0	80.0
I plan to maintain contact with my Bench-to-Bedside colleagues.	89.3	79.0	88.0	65.0

the summer institute; collaboration on action research proposal development, presentation and critiques; interactions with scientists and B2B staff; development and continual updating of a website with teaching strategy and content resources, participant action research proposals and final project reports; email communications between staff and participants and among participants, participants' sharing with school and district staff. In order to achieve lasting impact, mechanisms for continued support and interactions within an expanded biosciences community were enacted.

An education and training center staff member continues to promote regional teacher group collaborations throughout the school year, maintaining interactive websites (Facebook, B2B, and center websites) and supporting continually evolving partnerships with appropriate university and industry partners. B2B staff members are working closely with administrators and instructors in 2-4 year colleges to facilitate links with experienced B2B teachers to provide new opportunities for students in their shared communities.

Many B2B teachers went on to participate in other bioscience programs, e.g., Industrial Biotechnology or Mini Medical School, obtain grants (e.g. seed grant from American Society for Biochemistry and Molecular Biology), present at national conferences (NSTA and NABT) and publish results (*American Biology Teacher)*. Supplements to the original grant allowed for the creation of the Summer Research Experience which has thus far granted 28 teacher fellows the opportunity to develop standards-aligned curricular units based on the research interest of their host laboratory.

Discussion and Implications

Qualitative and quantitative evidence gathered indicates that the 3 aims of B2B have been accomplished, albeit in varying degrees. The qualitative aspect of the mixed methods research design allowed in-depth insights into teacher perceptions of the effectiveness of the summer institute that added meaning to the quantitative data, revealing the importance of addressing individual differences and variations in teacher needs and concerns (Barnes, Hodge, Parker & Koroly, 2006).

Findings suggest the summer institute provided a conducive environment for expanding teachers' biomedical/biotechnology awareness and expertise, which is in line with previous research in STEM settings (Capps & Crawford, 2013; Nadelson, Seifert, Moll, & Coats, 2012). Most teachers perceived that they learned relevant biomedical sciences content and skills that are congruent with their inquiry-based curricula grounded in national and state standards (Mueller, 2009; NRC, 2012). Scientists were effective professional developers, instructors, mentors, and resources, in line with approaches to scientist involvement in science education (Drayton & Falk, 2006) as mentioned previously.

In an effort to bridge the gap between institute biomedical sciences content and classroom implementation, action research (Mills, 2011) became the vehicle by which teachers planned, taught, and assessed biomedical sciences curricular infusion, sharing their efforts with peers and program staff. While acknowledging the benefits of the reflective nature of action research, some teachers were impeded by perceived constraints of the institute timeline, realities of their classroom settings, student background, and their own previous experiences with action research processes; many of these were addressed as their action research strategies were clarified and proposal sharing occurred (Vaino, Holbrook & Rannikmae, 2013). Mentoring during proposal preparation and feedback from project staff were critical elements to successful action research project completion and presentation. On the average, more than half the teachers indicated that they would conduct further action research.

Networking has continued post program via formal and informal means: returns to campus for symposium and other PD opportunities; an operational website with resources, posted action research proposals, and communication forums; and linkages with academic and industrial partners. The relationships and collaborations fostered through this program were cited by teachers and program staff as key benefits that would endure beyond the scope of this project, reflecting current sociocultural research and the value of learning in communities that employ professional discourse (Brown et al., 1989; Schoen, 2011).

Lessons Learned

Institute planning and modification occurred on a regular basis for each year of the program. Formative assessments were generally performed at the end of the summer institute, during the mid-year symposium, and at the end of the school year; these led to changes that can inform others who are planning similar teacher professional development:

- Modifying program structure to allow time for participants to identify their learning challenges (one-on-one and group sessions were effective).
- Moving action research instruction to early in the day and providing free time with coaching for proposal preparation (addresses fatigue and stress level associated with proposal draft completion).
- Including sessions with previous years' teachers who shared their action research proposals and implementation strategies (speaks to collegial sharing).
- Including multiple assessment and data analysis strategies with examples needed for action research proposal preparation.
- Emphasizing pacing guides, curriculum maps, and End of Course (EoC) Exam topics consistent with state and national standards.
- Assuring that appropriate technology support is present, including Internet access and portals into databases needed for action research literature reviews.
- Hosting all institute materials as part of the university E-learning classroom management system, providing teachers with access to all institute content and resources, a place to submit assignments and daily reflections (guided by prompts), as well as a forum for communication with university staff/faculty and fellow program participants).

Research has shown that high pressure, particularly in schools considered "at risk", influences school culture and severely challenges teachers' work (Leuhmann & Markowitz, 2007). Accountability pressure can be a significant barrier to implementation of new approaches to learning. As schools feel pressured to focus on topics that will appear on student assessments, successful professional development programs must consider these realities in order to serve the needs of all stakeholders involved. Successful professional development programs must reflect research-based principals of adult learning, including awareness of teachers' circumstances and support for innovation (Loucks-Horsley et al., 2010).

Conclusion

Action research can be an effective means of moving learnings from an intensive, content- and skill- rich institute into teachers' classrooms and measuring impact on student learning and interest. Interest was widespread in follow-up programs to expand and extend the B2B reach. Graduates of the institute might collaborate with university researchers and science educators to deliver school-based and regional in-service on using an action research model to infuse the biomedical sciences into their curricula. Clearly, further research should address some of the constraints identified and discussed in this study, such as aligning professional development goals with the realities of the teachers' classroom settings, as well as moving past the teachers' own previous experiences with action research processes. Additional work should also continue to search for viable links between science teacher professional development and meaningful classroom practice.

The biomedical sciences are a cutting edge focus for curriculum infusion, leading to a wide array of career opportunities. For those students who do not choose a traditional college path, the biotechnology industry offers entry-level technical positions. Regardless of career choice, students need to understand these concepts if they are to become informed citizens.

Educating our students in schools will assist in educating our communities. Educated communities allow for open-mindedness and understanding of new developments in science for public support (B2B teacher comment).

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