Lessons Learned from "BJC" CS Principles Professional Development

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ABSTRACT

Computer Science Principles (CSP) will become an Advanced Placement course during the 2016-17 school year, and there is an immediate need to train new teachers to be leaders in computing classrooms. From 2012-2015, the Beauty and Joy of Computing team offered professional development (PD) to 133 teachers, resulting in 89 BJC CSP courses taught in high schools. Our data show that the PD improved teachers' confidence in our four core content categories and met its primary goal of training teachers in equitable, inquiry-based instruction. In this paper, we present the evolution of the BJC PD, its challenges and lessons that we learned while continually adapting to teachers' needs and contexts.

Keywords

Professional Development; Computer Science Principles

1. INTRODUCTION AND BACKGROUND

Computer Science Principles (CSP) is a new course designed to appeal to a broad audience and provide high school students with an introduction to computing [2]. CSP will become an Advanced Placement course in 2016-17 and is a key part of the National Science Foundation's CS10K project which aims to teach 10,000 new, highly qualified high school teachers in computing. Since 2012, we have been offering professional development (PD) to help prepare cohorts of teachers to teach the Beauty and Joy of Computing[1] (BJC) version of CSP. The BJC course and PD support novices in learning computing using the Snap*!* visual programming language and emphasize equitable pedagogies, such as pair programming. In this paper, we report outcomes and lessons learned through 4 years of BJC PD workshops with 133 high school teachers. By conveying the story and outcomes of our program, we hope to contribute to a better understanding of teacher PD for CS.

In the last few years, a growing body of research has focused on CS PD for K-12 teachers in the US [5, 7, 8, 9]. The Exploring Computer Science (ECS) curriculum built by Joanna Goode, Jane Margolis and colleagues is taught in PD using strategies from educational research [7]. It emphasizes inquiry-based learning, teacher-learner-observer models and cultivating a professional learning community. These central features of the ECS PD provide teachers with pedagogical content knowledge and time to collaborate. The PD emphasizes active, engaged and creative learning and models what should take place in the ECS classroom.

Gray's CSP PD project found that providing time for teachers to collaborate is an important aspect of successful PD [8]. Leaders from the Mobile CSP PD [9] and Chicago's Taste of Computing PD [6] found it important to provide a positive experience for teachers so that teachers will be more likely to use the full curriculum in their courses. The BJC PD project described here supports these findings, and evolved to emphasize teacher collaboration during the PD.

In addition to the challenges of learning CS content and pedagogy, high school CS teachers are uniquely isolated, often with only 1-2 teachers teaching CS courses at a given school, or even in a whole district. The "current isolation of HS CS teachers further indicates the need for supporting [these teachers]" [10]. Communities of practice support learning "in part through social interaction and the circulation of narrative." These "groups of practitioners are particularly important, for it is only within groups that social interaction and conversation can take place" [3]. BJC PD provides a community of practice throughout the school year in a Piazza forum and monthly meetings online.

2. THE BJC CS PRINCIPLES PD

The goal of our PD project was to train 100 teachers and have 50 teachers adopt the BJC CSP course. BJC features weekly pair-programming labs, a final project of the students' choosing, lectures that highlight computing topics from artificial intelligence to the internet, and discussions on current events and the Blown to Bits text [1]. The BJC PD centered on learning the principles of computing through hands-on, collaborative labs, and learning to use equitable

[1] bjc.berkeley.edu

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pedagogies known to support women, underrepresented minorities, and students with less prior computing experience. From 2012-2015, we exceeded our goals, with 133 teachers participating in PD and 51 going on to teach a BJC course, for a total 89 courses.

The BJC PD lasts 6 weeks, with Weeks 1 and 6 held in person and Weeks 2-5 held online. All teachers in the PD are initially added to Piazza - an online question and answer wiki and forum we used to organize the PD schedule, resources, and teacher work and questions. Week 1 prepares teachers to learn the programming content with hands-on lessons on the first 5 Snap*!* labs, taught just as teachers are expected to teach the labs in class, using pair programming. During Weeks 2-5, participants complete the remaining labs and readings, as well as the CSP "Create" and "Explore" tasks[2]. In the Create task, students work in pairs to create a program, while the Explore task is a writing assignment to report on the potential benefits and harms of a computing innovation. Week 6 emphasizes methods for recruiting and supporting diverse students, mapping the curriculum to each teacher's specific course schedule, as well as pedagogical content knowledge (PCK), or "how to teach CS." These PCK methods include pair programming, ways of connecting computing to students' daily lives, ways to help students reflect on the impacts of technology, and ways to motivate BJC topics, such as CS Unplugged activities.

In the remaining sections, we discuss the evolution of the BJC PD in three main phases: the pilot year (2012), the restructuring year (2013), and the evolved PD (2014-15). The PD is held at two primary sites, in North Carolina (NC) and California (CA). We focus here on experiences from the NC site, which were distinct in Phase I but similar to CA for the remaining years.

2.1 Phase I (2012)

In 2012, the NC Department of Public Instruction recommended 10 Career and Technical Education (CTE) teachers to take the BJC PD. Since these CTE teachers had experience teaching high school programming courses, we assumed that teachers were fluent in both CS and in PCK for CS. In Week 1, teachers worked all the labs, with the PD facilitator discussing how each lab related to a larger CS context. For Weeks 2-5, teachers were asked to adapt an existing BJC unit into a lesson plan for their own classroom, instead of finishing the BJC course as students would. In Week 6, teachers presented their lesson plans to one another. Two of the teachers created quality lesson plans, with the remaining teachers creating powerpoint slides, or web resource links. Few teachers reported making contact with each other over the summer, and those teachers who did attempt the assignment felt the directions were unclear.

By the end of the PD, it became clear most of the participating teachers were not fluent in either CS content or CSP pedagogies. Many teachers only had experience teaching business and software applications courses, and even those who had taught programming courses were underprepared to discuss CSP from an advanced perspective. Because we assumed more expertise than the teachers possessed, the level of PD instruction was too high, and teachers felt unprepared to teach BJC the way it was presented. We learned that teachers want and need to be taught as if they were students in the course, so they can model their teaching after their experiences in the PD. Further complicating matters, many teachers had already been assigned their course schedule for the following year, and knew they would not be teaching a BJC course, leading to a lack of motivation to learn the material. To address these problems, we implemented major PD revisions for 2013.

[2]www.apcsprinciples.org

2.2 Phase II (2013)

In 2013, we required certification that teachers would be teaching CSP within the next 2 school years but assumed no prior CS or pedagogical content knowledge. We also invited PD alumni back for Week 6 to review and prepare for future courses, and to help newer attendees. The PD focused on training teachers from the ground up, to understand both the CS content and the pedagogy for BJC. Week 1 still focused on the use of Snap*!* and the CS concepts in each lab. However, instead of emphasizing computational elegance in each lab, we emphasized basic guidance on using the programming interface and accomplishing the lab goals. Teachers were required to work in pairs, to learn together, answer each other's questions, and help debug programs. In Weeks 2-5, teachers were requested to complete the BJC course online, and to use Piazza to ask questions and collaborate. In Week 6, teachers collaborated to adapt the BJC curriculum to their own high school scheduling constraints. One teacher in particular stood out, developing a pacing guide, curriculum blueprints (mapping the CSP curriculum framework and learning objectives to BJC labs and units), and sample exam material. Because of these efforts, we were able to promote the course, since each of these documents was required for wider adoption in our state high schools. This experienced teacher was an invaluable resource to other teachers both during and after the PD, demonstrating the value of sharing expertise among teachers and creating a community for their ongoing mutual support.

2.3 Phase III (2014/2015)

Based on our observation that teachers were more satisfied with the PD the more they interacted with other teachers, we shifted PD leadership from university faculty to experienced high school teachers and PD alumni. We expanded emphasis on strategies for recruiting and diversity, and collaborative lesson planning, with high school teacher facilitators. To prepare these 'master teacher' facilitators, a new branch of the PD was created specifically to train master teachers to lead BJC PD on their own.

In Week 1, experienced high school teachers were brought to the PD from the Tapestry Workshop [4]. Tapestry is a community of teachers and professors sharing strategies, research-based practices, and field-tested ideas for teaching CS in a way that reaches all students regardless of sex or ethnicity. On the last two days of the Week 1 PD, the Tapestry teachers shared their strategies for pedagogy and recruiting diverse students into their computing courses. The BJC PD teachers valued the time and insights from fellow teachers and suggested that we continue to emphasize peer teaching.

The main BJC PD is now run primarily by high school teachers, who lead 60-80% of the workshop content, with BJC professors leading more advanced topics by request of the attending teachers. Flexibility is scheduled into the PD so that teachers can request further discussion on topics they find relevant. The first week is still primarily geared towards understanding Snap*!* and the BJC mission. During the

					Taught BJC	
Year	CA	NC	Total	Alum	Total	New
2012	12	13	25	–	7	2
2013	9	12	21	3	29	21
2014	38	17	55	8	24	17
2015	18	14	32	21	29	11
Total	**77**	**56**	**133**	**32**	**89**	**51**

Table 1: The number of teachers who attended each PD site and the number of confirmed BJC courses taught. We also include the number of "Alumni" teachers who attended more than 1 PD.

four-week online course, teachers complete the remaining BJC curriculum through an edX MOOC (Massively Open Online Course). This same course can then be used as a resource for participants when they teach the material to their own students. Piazza is used for answering questions and maintaining notes and discussion over the course of the whole PD, and later serves as a way to keep in touch and troubleshoot over the school year.

The PD Week 6 focuses on pedagogy and teaching strategies specific to computing and BJC, i.e. PCK. Teachers work in groups to develop a lesson plan for a BJC unit of their choice, and give short presentations to the rest of the teachers so they can use each other's plans in the coming year. This in-class presentation of ideas allows teachers to take ownership of the course, demonstrating their own ability to teach the material. In addition, these teacher-led lessons provide opportunities for teachers to reflect on the course as students and observers.

2.4 Summary

In the first 3 years of the PD for the BJC curriculum, we actively adapted the PD course to improve our instruction, to better support teacher learners from diverse backgrounds and to individualize their learning experience to meet their needs. We worked to centralize online support and resources, which were originally spread across many platforms. Our teaching practice shifted from having university faculty explaining the intricacies of the BJC curriculum, to having teachers training fellow teachers to understand and teach CS concepts. Our initial, rigid schedule was adjusted to allow extra days to explore the topics participants found most interesting. These changes led to a PD that was more effective and led to higher teacher confidence and adoption, as is explored in the next section.

3. OUTCOMES

To assess the outcomes of the BJC PD, we surveyed participants before and after attending the PD. For participants who went on to teach a computing course, we collected post-course surveys from both the participants and their students. Previous work has investigated student post-course surveys [11], suggesting that the course was generally appealing to students, and the BJC curriculum was equally effective for students from diverse backgrounds. Table 1 shows the number of teachers who attended the PD from 2012-2015 and how many BJC courses were taught each year. These numbers only include courses we could *confirm* through surveys and forum posts and likely underestimate the true numbers. During this time, we were also able to train over 80 teachers across the U.S. in shorter BJC workshops. In the remainder of this section, we will focus on analysis of the pre- and post-PD surveys from the summer 2014 PD at the NC and CA sites, for which we have the most complete data (2015 survey data was not available at the time of this writing).

Gender:	Female	20	54%
	Male	17	46%
Race/ Ethnicity:	American Indian	0	0%
	Asian	3	8%
	Black/African-American	4	11%
	Hawaiian/Pacific Islander	1	3%
	White	28	76%
	Hispanic	6	16%

Table 2: The 2014 PD participant demographics.

3.1 Population and Survey Content

The pre-PD survey included 57 participants: 38 attended in CA; 13 attended in NC; 6 attended at both CA and NC. The post-PD survey included 50 participants: 32 attended in CA; 12 attended in NC; 6 attended at both CA and NC. In total, 37 of the respondents completed both pre- and post-surveys. Any analysis comparing surveys was limited to these respondents. Respondents had an average of 10.7 years of teaching experience (range = 0-40; median = 9.5) but an average of only 3 years of experience teaching CS (range = 0-22; median = 1). Demographic information is presented in Table 2.

The pre-survey included a number of questions on participants' backgrounds, including demographics, the number of years they had taught in K-12 and high school classrooms, the number of college-level CS courses they had taken and any degree or teaching certificates they had been awarded. Participants also reported any computing courses they had taught previously, or anticipated teaching. The post-survey asked participants to rate various aspects of the PD on a 5-point scale, including applicability, efficacy, quality of instruction and use of time. Participants were also asked to give an overall rating to the PD on a 5-point scale.

Both the pre- and post-surveys included a set of identical questions to assess the effects of the PD. Participants were asked what percent of their course they expected to be based on the BJC materials. They also reported their perceived ability to teach a CS Principles course in four categories which correspond to the goals of the BJC curriculum: Content, Inquiry, Equity and Differentiation. Each category consisted of 6 to 13 five-point Likert scale items.

Content questions asked participants to rate their fluency with CS principles concepts and teaching tools. Inquiry questions concerned participants' ability to foster inquiry and engagement within their students in CS courses. Equity questions concerned participants' ability to teach equitably and incorporate elements of social justice into their instruction. Differentiation questions concerned participants' ability to teach to a diverse student body, including students with physical or learning disability, racial/ethnic minorities and females. All responses were self-reported and reflect perceived abilities.

3.2 Teacher Ratings of the PD

The PD was well-rated overall, with 76% of post-survey respondents describing it "Excellent" or "Above Average."

Category	Pre	Post	p<	*d*
Content	2.726 (0.742)	2.962 (0.649)	0.001	0.338
Inquiry	2.431 (0.683)	2.633 (0.559)	0.025	0.341
Equity	2.562 (0.801)	2.862 (0.663)	0.025	0.408
Diff.	2.403 (0.761)	2.742 (0.686)	0.005	0.467

Table 3: Average scores (and standard deviations) in each of the four categories for the pre- and post-survey. Each showed a significant improvement. P-values and Cohen's *d* (effect size) are given.

Participants also rated a number specific aspects of the PD:

PD facilitators were highly rated, with 88% of respondents agreeing or strongly agreeing with the statement "The facilitator was knowledgeable and helpful," 84% with the statement "The facilitator was well prepared," and 87% with the statement "The facilitators helped me understand how to implement my learning." In the 2014 PD, instructors included both university faculty and returning teachers, who had previously taken the PD and taught a BJC course. When asked the best aspect of the course, many mentioned the quality of instruction and instructors:

The instructors were great. [The facilitators] were all excellent. I especially loved the different point of views, opinions, and approaches they all took. As someone that is new to teaching (especially regarding CS), it was valuable to provide such a diverse set of instructors and modeling.

The PD content was also well rated, with 89% of respondents agreeing or strongly agreeing with the statement "The content of the professional development is relevant to my professional responsibilities" and 95% with the statement "This professional development will extend my knowledge, skills, and performances."

Participants also noted areas where the PD could be improved, specifically in the area of organization and time management. Only 52% of respondents agreed or strongly agreed with the statement, "Time was used efficiently and effectively," and 62% with the statement "The professional development goals and objectives were clearly specified."

I know that you were trying to be flexible, but at times in Week 6, I didn't feel like the schedule was well planned out and followed. There were times when we get a topic that was really interesting and then it would cut short for one that wasn't so interesting.

3.3 Perceived Ability to Teach a BJC Course

To assess the impact of the PD on teachers' perceived ability to teach CSP, we investigated their pre- and post-survey ratings in each category: Content, Inquiry/Engagement, Equity and Differentiation. For each category, we summed item responses to produce a numeric value, and tested for differences between pre- and post-survey responses using a Wilcoxon signed-rank test, as the data did not appear normal. In each category there was a significant improvement, as shown in Table 3.

3.4 Modeling PD Outcomes

To understand the potentially differential impact of the PD based on the prior experience of participants, we investigated the relationship between participants' teaching experience and various outcome measures of the PD's effectiveness. The pre-survey attributes we investigated were:

Content	`Pre`	`CS`	`HS`	$\mathbf{R^2}$	**p <**
M1	0.699**			0.663	
M2	0.639**	0.342**		0.732	0.005
M3	0.630**	0.276*	0.232+	0.764	0.05
Equity	`Pre`	`K12`			
M1	0.424**			0.247	
M2	0.394**	0.418*		0.378	0.05

+ $p < 0.1$, * $p < 0.05$, ** $p < 0.005$

Table 4: The construction of models for post-survey Content and Equity ratings. Each row shows Beta-weights for the model produced by adding an additional variable. R-squared is given for each model, along with p-values from comparing each model to the previous. The final model for each category is last, in bold.

number of years teaching high school (`HS`), number of years teaching K-12 school (`K12`), and number of college-level CS courses taken (`CS`). Each of the numeric variables was converted to a binary value, where the variable was true if the participant had at least the median years of experience. The PD outcomes we investigated in the post-survey were: perceived ability to teach CSP in each of the 4 categories, and how much of future course curricula the teacher intended to base on BJC.

We used a linear regression to model the relationship between each outcome variable and the binary attribute variables. In each of our models, we included the pre-survey response as a covariate. We built the models in a forward step-wise fashion, using Akaike Information Criterion (AIC) as our selection criterion to balance model complexity with accuracy. After each model was computed, we added the variables in, one at a time, and stopped if any variable failed to produce a statistically significant improvement in the model, as measured by an F-test. After this procedure, two models were non-trivial and are given in Table 4.

The first model suggests that Content understanding improved more after the PD for participants with at least the median 2 college-level CS courses. The model also suggests a similar trend for high school teaching experience, but the teaching experience variable was not significant. Similarly, the second model suggests that Equity understanding improved more after the PD for participants with at least the median 8 years of K-12 teaching experience.

It is important to note that these models are intended to be descriptive rather than predictive. For instance, the first model can be interpreted to say that participants without a CS background are getting less out of our CS content instruction, and additional effort is needed to help them keep up. We offer this as an example of how data can be used to inform future PD instruction, rather than relying solely on anecdotal evidence.

3.5 BJC Adoption

One of the primary goals of the PD was to encourage and enable teachers to teach a BJC-based course. To better understand the impact of the PD on teacher intentions to teach BJC, we compared participant responses to the question "About how much of your course do you expect to be based on BJC materials?" on the pre- and post-surveys. The distribution of pre and post- survey responses is shown in

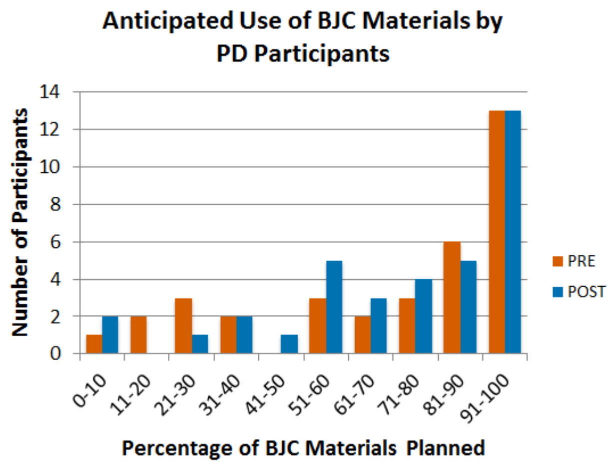

Figure 1: Anticipated BJC use reported in the pre- and post-surveys. Despite similar distributions, pre-survey responses were not predictive of post-survey responses.

Figure 1. On the whole, we see the majority of participants intend to use most or all of the BJC curriculum. Historical data from Table 1 suggests that in reality, adoption rates are not this high. While the distributions look quite similar, it is important to note that many participants' intentions did change from pre to post, but the changes were in different directions for different teachers. In fact, the Spearman rank-order correlation coefficient between participants' pre- and post-survey responses to this question was 0.33. This tells us that participants' understanding of the BJC curriculum, and how the curriculum can meet their needs, evolved over the course of the PD.

4. CHALLENGES AND LESSONS

Throughout the previous sections, we have noted many of the considerations, challenges and lessons learned in designing and iterating on the PD. Here we highlight some of our key findings, which can be used to improve future PD.

4.1 Challenges and Our Responses

Evaluation. It is difficult to measure exactly how successful the PD was in encouraging participants to teach BJC courses. For instance, from 2012-2014 we sent out yearly surveys to our PD participants during the school year to determine if they were teaching BJC that year; however, our response rates were low, ranging from 31-50%. We also offered stipends to teachers with BJC courses who were willing to respond to short surveys once every two weeks, giving a quick update on the material they had taught, the tools they used and how the students perceived the material. However, we struggled to convince busy professionals to take time out of their days to respond during the school year, and response rates remained low. Because the data we do have comes from those participants who chose to respond to surveys, and many of these are the most enthusiastic teachers, this data is likely to be strongly influenced by selection bias.

Response: Instead of impersonal surveys, we found that offering a single in-depth interview in-person at the end of the semester evoked a better response rate and provided us with more detailed data. For the pre- and post-PD surveys, we found that giving participants time to complete the survey during the PD ensured a high response rate and a representative sample. We also found that forum activity offered good, if incomplete, evidence of teachers' adoption of BJC. The adoption numbers reported in Table 1 come largely from confirmations on the Piazza forum. However, because most online forums, including BJC's Piazza, have low average participation, it is likely that we have underestimated the number of teachers who have taught BJC.

Institutional Barriers. One consistent challenge throughout the PD was helping newly-trained participants to implement a computing course at their institutions. Despite training 133 new teachers from 2012-2015, we could only confirm that 51 (38%) went on to teach a BJC course. We found that institutional barriers played a strong role in preventing PD participants from teaching a BJC course. Some teachers came into the PD assuming they would be teaching a computing course the next semester, only to see that course changed, delayed or canceled by administrators. Changing administrative policies can also affect computing courses. One school district, for instance, implemented a policy which limited each school to teaching no more than two different programming languages. Some impacted teachers were forced to alter their curricula to compensate, while others were unable to teach the course. In many districts, high teacher attrition rates exacerbate these problems.

Response: While we cannot directly control institutional policies, we have found that these problems can be mitigated to some extent by providing teachers with adequate support and encouraging community once the PD has concluded. We accomplish this in part through a forum on Piazza where teachers can post challenges they face (both institutional and content-based) and facilitators and other teachers can provide support. We further encourage formation of and participation in local chapters of the Computer Science Teachers Association (CSTA), which provide a similar support function.

Teacher Communities. While strong communities can provide invaluable support to participants as they transition into teaching a computing course, developing those communities is a serious undertaking. Our participants came from across the United States, many from districts where they may be the only computing teacher. Others came from remote or rural areas, making it difficult to be involved in support groups, such as the CSTA, when meetings are far away. For those that do have access to a community of computing teachers, their resources and curricula are often diverse and fragmented, making it difficult for teachers to share them and offer support.

Response: We addressed this in part by creating a virtual community for our participants. They have access to various online resources, such as a Piazza support forum, a resources wiki[3], and the edX course, with activities for their students. The Piazza forum has over 350 members, 31% of whom have actively posted, with almost 200 questions answered by members (30%) and instructors (70%) alike. By giving teachers shared training, shared resources, and a shared space for addressing problems that arise, we hope to give them the support they need, even if it is not

[3] beautyjoycomputing.wikispaces.com

available at their institution. However, this is not a comprehensive solution. We still find that many teachers use these resources when a problem arises (posting on the forum, using a resource in the wiki), but it is much more difficult to get participants to contribute content, for instance, by adding to the wiki. These responsibilities are still largely fulfilled by PD facilitators.

4.2 Lessons Learned

Address Participants' Needs. The BJC curriculum was initially designed for college students. However, AP courses are meant to be taken by high school students for college credit, so it was important that our PD meet the needs of high school teachers. This required a number of adjustments along the way. Because our original facilitators were university faculty, they naturally taught the PD in a way that would meet the needs of professors like themselves, providing resources and a framework for using them, paced for a semester's duration. This did not match the needs of our participants, who were accustomed to year-long courses, or semester-long courses with significantly more contact hours, with detailed lesson plans provided to teachers in advance. An experienced high school teacher helped us to develop a more detailed pacing guide that participants found much more useful. In addition, we encouraged PD alumni to attend PD in subsequent years to provide them with more time and opportunities to learn enough computing and pedagogical practices to prepare them for the classroom.

Model Teaching in the PD. The first year that we taught the PD, we expected participants to come in with a background in CS and experience with pedagogy and lesson planning. As such, the PD focused on the importance of the high-level concepts in the BJC curriculum. In reality, our participants came from diverse backgrounds, with a variety of teaching experiences, and many had no CS experience at all. We learned to recognize that our teachers were students themselves, and they needed to understand the BJC materials before they could learn to teach them. This gave us the opportunity to use the PD to model how to teach the BJC curriculum to a group of diverse learners. Drawing upon lessons learned from other CS PD, e.g. [7], we adapted the course to focus on inquiry-based learning, with teachers exploring the materials as their students would, and later presenting this back to other participants as teachers.

Encourage Community through Collaboration. We have stressed the importance of community in helping participants to overcome the institutional and classroom challenges that come with teaching a new course. We have found that one of the most effective ways to encourage community during the PD is through collaboration on assignments. The BJC curriculum is already designed to foster collaboration among students, with an emphasis on pair programming and team assignments. Getting teachers to model this during the PD not only shows them the importance of collaboration for their students; it helps to form the basis for the community that will help support them throughout the coming semesters.

5. CONCLUSIONS

The BJC PD led to the training of 133 teachers and at least 89 implemented high school courses. Our data show that the PD improved teachers' confidence in each of our four core content categories, and met its primary goal of training teachers in equitable, inquiry-based instruction. To accomplish this, we had to constantly adapt the PD, think creatively, and borrow the best ideas from other PD efforts, in order to provide more opportunities for teachers to experience the content and connect with a supportive community. Our hope is that this account and analysis will help other PD facilitators to learn from our experience and create more effective PD in the future.

6. ACKNOWLEDGEMENTS

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