Collaborative Research: Research, Dissemination, and Faculty Development of Inquiry-Based Learning (IBL) Methods in the Teaching and Learning of Mathematics

Cumulative Evaluation Report: 2010-2013

Charles Hayward and Sandra Laursen
Ethnography & Evaluation Research, University of Colorado Boulder
February 2014, corrected September 2014

Executive Summary

This report details findings from the evaluation of four annual workshops hosted at the IBL Centers[1] from 2010 to 2013 and supported by the National Science Foundation. The workshops were designed to introduce participants to inquiry-based learning (IBL) instruction and show them how to teach a course that has been fully developed in that style. Each intensive, four- or five-day workshop had its own unique schedule, but they all included similar activities such as talks from invited speakers and discussion panels. Participants at the different workshops engaged in activities such as watching videos, reading and discussing research articles, listening to plenary talks, participating in panel discussions with experienced IBL instructors, observing and discussing IBL classes, and developing IBL materials.

As evaluators for the IBL Centers' workshops, we gathered data to identify who participated, what they did or did not gain from participation, and their perceptions and advice about workshop activities and logistics. To do so, we conducted online pre-workshop surveys, in-person post-workshop surveys, and online follow-up surveys one academic year after the workshop with each workshop cohort.[2] Generally, response rates were high. Of the 167 participants at the four workshops, 87% completed the pre-surveys, 90% completed the post-surveys, and 67% completed the one-year follow-up surveys. Using anonymous identifiers to match individuals' surveys from different times, we were able to successfully match 80% of post-workshop surveys and 72% of follow-up surveys to the pre-workshop surveys. Additionally, we conducted follow-up interviews with a subset of 16 participants from the first two workshops (2010 and 2011).

Participants at the workshop were fairly diverse; females and minorities were represented in proportion to mathematics faculty as a whole. Participants represented a variety of career stages and lengths of teaching experience, including new, untenured faculty as well as tenured faculty with more than 20 years of experience. Participants came from different types of institutions, mainly four-year colleges and Ph.D.-granting research universities. About 13% taught at Minority-Serving Institutions. About half of participants had no prior experience with IBL as instructors or as students. However, participants expressed high motivation to use IBL and strong beliefs in its effectiveness prior to the workshop. Hence, they entered as already motivated and interested participants.

[1] At the Universities of Chicago, Michigan, Texas at Austin, and California-Santa Barbara.
[2] One-year follow-up surveys for the 2013 cohort will not be collected until Fall 2014.

Overall, almost all participants rated the overall quality of the workshop, as well as the logistics, as 'good' or 'excellent.' Quality ratings were significantly higher for the 2010 workshop than the other three, and logistics ratings were significantly lower for the 2011 workshop than the other three. However, all four workshops seemed to successfully meet their goals of introducing participants to IBL and showing them how to implement IBL methods in their own courses: following the workshop, participants reported greater knowledge about IBL and skill in implementing it, as well as increased motivation and belief in its effectiveness. One year later, knowledge and skill remained at the post-workshop levels. Belief in the effectiveness of IBL dropped slightly, though remained higher than pre-workshop levels, and motivation to use IBL returned to pre-workshop levels. The post-workshop spike in motivation may be instrumental in getting participants to start implementing IBL in their own classrooms**.**

Implementation of IBL

Many participants from the 2010, 2011, and 2012 workshops reported implementing IBL in their own courses. (Follow-up information for the 2013 workshop will be collected in Fall 2014.) At least 58% of participants used some IBL techniques in the year following the workshop, including 29% that taught a 'full' IBL course and 29% that implemented some IBL methods along with traditional methods. However, that is a conservative estimate, counting non-responders as non-implementers. In comparison, of those that responded, 88% reported using at least some IBL methods. These implementation rates are high, especially given participants' comments on the extensive amount of time required to develop an IBL course.

Reported implementation rates were higher for the 2012 workshop than the 2010 and 2011 workshops. This may be related to follow-up activities; the 2012 workshop is the only one of the three that has had consistent follow-up engagement of participants, largely through an e-mail listserv. On the listserv, which includes both participants and workshop facilitators, members checked in and cheered each other on, as well as shared ideas and posed and responded to difficulties individual instructors were facing with implementing IBL in their classrooms. In the year following that workshop, 62% of workshop attendees, and 65% of all list members were active on the list.

In addition to their self-categorized implementation level, participants reported the frequency with which they used different instructional strategies on both pre-workshop and one-year follow-up surveys. Comparisons of individuals' responses revealed *decreased frequencies* of:

- Instructors lecturing
- Instructors solving problems at the board

Participants also indicated *increased frequencies* of:

- Student-led whole class discussions
- Students discussing in small groups
- Students presenting problems or proofs

Overall, these changes are consistent with inquiry-based learning and a shift from instructor-centered activities to student-centered activities. Comparisons on non-IBL specific techniques, such as computer-assisted learning or instructors asking conceptual questions, did not change significantly. Moreover, changes in teaching strategies seemed to be sensitive to the presentation of IBL at the workshops. Some participants were presented with a Modified Moore Method representation of IBL, characterized by student

presentations and rigorous discussion, while other were presented with a group work-based representation of IBL. Participants who were presented with a Modified Moore Method representation of IBL reported *greater increases* in frequency of student presentations than those that were presented with group work-based IBL.

Further, in interviews conducted with a subset of participants from the 2010 and 2011 workshops, participants provided more detail about their classroom practices. While those who classified themselves as "full" IBL implementers described using the Modified Moore Method almost exclusively, "partial" IBL implementers revealed a broad spectrum of practices. This included some who used IBL techniques for part of each class, some who split their courses between lecture days and IBL days, and some who started with lecture but gradually changed to full IBL throughout the course of the semester. Coming to see IBL as a broad "spectrum" of practices seemed to be important in helping participants to become implementers, as gradual steps seemed more feasible than completely redesigning and entire course. In fact, one participant explained that, "The Moore Method is something that I don't feel comfortable applying. But, feeling like I can pick and choose aspects of [IBL], and find something on the spectrum that I feel comfortable with, was empowering." We discuss other factors affecting implementation in the full report.

Implementation Barriers

On post-workshop surveys, participants commented on the concerns that they still had with implementing IBL. The three most frequent concerns were:

- IBL's in-depth approach makes it difficult to cover enough material
- Student buy-in to new IBL techniques
- Lack of instructor skill to implement IBL

These three biggest concerns were important topics discussed during the workshops. While facilitators did share strategies for dealing with coverage and buy-in issues directly, these concerns also likely dissipate over time as instructors practice and gain skill with IBL.

In addition to these survey responses, interview participants provided detailed information about the factors that affected their implementation of IBL. Participants experienced actual barriers, the biggest of which were student resistance, instructors' fears that they would not be successful in using IBL, and lower student evaluations. Participants were largely able to overcome these barriers, as 15 of the 16 interviewees had implemented IBL to some degree.

Implementation Supports

Supports that participants identified may have helped them to overcome these barriers, and commonly included:

- Departmental support
- Additional IBL-related professional activities
- Mentors or IBL colleagues

Departmental support was identified most frequently in the interviews, and in fact, on follow-up surveys, 85% to 90% of participants reported at least moderate support from each of three distinct but important groups: departmental colleagues, department chairs, and provosts or deans. Although departmental resistance was mentioned relatively commonly on pre-workshop surveys and in person during the workshops, most participants in fact reported feeling supported when they actually tried to implement IBL.

Interviewees also identified the IBL community as supportive. This included other IBL-related professional activities such as Project NExT, the 'Legacy of R.L. Moore' conference,

colleagues using IBL, and IBL-focused events at large professional meetings. Three of the workshop facilitators, Mike Starbird, Carol Schumacher, and Stan Yoshinobu, were named as particularly helpful. Interviewees cited talks these individuals gave, books they wrote, and personal conversations and mentoring as valuable developmental activities.

Implementation Considerations

In addition to barriers and supports, interviewees also commented on considerations they made when implementing IBL. Rather than being barriers, or actual problems they encountered, these comments focused on issues instructors thoughtfully addressed in order to implement successfully. Thus they may provide the best picture of what topics workshops should cover to be most useful. Indeed, many of these topics were addressed in the workshops, including:

- IBL-appropriate materials
- Changing of instructors' role
- Techniques for student participations and assessment
- Student buy-in and marketing
- Situational factors (class level, class size, student audience, physical space)

The two most mentioned considerations dealt with two big changes instructors needed to make, IBL appropriate course materials, and the changing role of the instructor. Whereas most traditional instructional materials are designed to show coherent solutions or proofs, IBL materials instead aim to set up explorations where students can successfully make sense of the material by discovering solutions or proofs themselves. Instructors sometimes used already-created IBL materials, often modifying them for their own purposes, or developed them from scratch. Just as materials were designed to encourage students to do the sense-making for themselves, instructors' roles shifted from presenters of knowledge to facilitators helping students to construct their own knowledge. These two considerations were addressed in the workshops, as the 2010 and 2012 workshops gave participants extensive time to develop IBL materials and all workshops addressed the shift in instructors' roles through a mix of invited talks, discussions, videos, and in-person observations.

As instructors' roles shifted and students became more active participants, instructors developed techniques to support the new environment. Instructors brought out student participation partially by providing incentives. For many, this included making it part of their grade, but others also had methods to promote equitable student participation such as computer-generated 'priority trackers' to keep track of who had presented.

Since these changes were new for many students, instructors were careful to explain the rationale for using IBL techniques to their students. It was important for instructors to get student buy-in through this 'marketing' at the beginning of the course, but also to maintain morale throughout the term.

While these most frequent considerations all relate to classrooms where instructors implemented IBL techniques, instructors also commented on situational factors that determined whether or not they would try implementing IBL. They considered things like the number of students in the class, the level of the class, the student audience, and the physical space available. There was no general consensus as to what was best for each, as interviewees used IBL in a variety of settings. However, they did affect the shape of IBL courses. For example, large classes could use group work instead of individual

presentations, while theater-style seating made group work difficult but may have been fine for presentations.

Conclusions

Overall, the workshops served a diverse set of participants who were highly satisfied with the quality and logistics. Though participants entered the workshops already holding strong beliefs in the effectiveness of inquiry-based learning, they reported significantly stronger beliefs after the workshops. Participants also reported significant increases in their knowledge about IBL and skill in implementing IBL.

Despite expressing many concerns, most participants reported implementing IBL practices in their own classroom during the year following the workshop, and many planned to use IBL techniques in future classes as well. Changes in reported teaching practices supported this, and indicated a shift from instructor-centered lecture models to more active student participation including group work, presentations, and discussions.

Participant interviews supported self-reported implementation results and provided more detailed information about classroom practices. Participants identified some barriers to implementing IBL, but by thoughtfully designing their courses, most reported successfully using IBL methods in the year following the workshops they had attended. Participants spoke about how gaining understanding of the spectrum of IBL techniques made IBL more accessible, and how experienced practitioners from the workshops served as valuable mentors.

Additionally, survey findings, along with interview participants' reflections on their own development, reveal common themes that future workshops can use to help participants successfully adopt IBL techniques, including:

- Exposure to a broad 'spectrum' of IBL varieties, with discussions about the new roles for instructors and students
- Time and resources for developing IBL-appropriate course materials
- Specific strategies to deal with some of the major concerns of IBL implementers (i.e. student buy-in/resistance, marketing, coverage, techniques for participation, etc.)
- Ongoing support and inclusion in the broader community of IBL practitioners

Taken together, all evidence indicates that these workshops have helped participants make the transition from being observers interested in IBL to becoming IBL practitioners. The findings have also helped to reveal important factors for instructors beginning to make the change from instructor-centered methods to student-centered and inquiry-based classrooms, and how workshop facilitators can support them in making the transition.

Table of Contents

Project Overview

Inquiry-Based Learning (IBL) is a student-centered approach to learning. In contrast to the traditional lecture methods, IBL puts the focus of learning on student creation, exploration, communication, and criticism of ideas, while still under the guidance and support of faculty. The techniques of instruction shared in this project are founded on methods used by the late R. L. Moore, but are generally consistent with the current scholarly understanding of how people learn.

In 2004, with funding from the Educational Advancement Foundation, IBL Centers were established in the mathematics departments at four universities around the United States. The purpose was to develop, broaden, and study the use and effectiveness of IBL mathematics instruction at the Centers themselves and eventually to disseminate this work to other colleges and universities. The present project, separately funded by a collaborative award from the National Science Foundation to the four IBL Centers,[3] seeks to disseminate the use of IBL as an effective method of teaching college mathematics to a wide range of mathematics departments. To achieve this goal, the project provides hands-on, intensive, professional development workshops for faculty interested in learning about IBL methods. In addition to IBL practitioners from the Centers, others from the broader IBL community of practice have participated as presenters, panelists and facilitators at the workshops.

The workshops are designed to introduce participants to the IBL style of instruction and show them how to teach a course that has been fully developed in that style. The workshops are intended for participants new to IBL, but who may or may not have had some previous experience with IBL techniques. Preliminary readings, email or personal discussions, the intensive week-long workshops, shared written and/or electronic materials, and post-workshop mentoring are all aimed at stimulating mathematics faculty to offer inquiry-based courses at their own institutions. After the workshop, organizers proposed to connect participants to a mentoring support system to help them as they implement these ideas in their own classrooms.

As evaluators for the IBL Centers' workshops, also funded by NSF, we have gathered data to identify who participated, what they did or did not gain from participation, and their perceptions and advice about workshop activities and logistics. In separate reports, we provided results from these data on each of the first three workshops, held in 2010 at the University of Texas at Austin (Kogan & Laursen, 2010), in 2011 at the University of Michigan (Kogan & Laursen, 2011), and in 2012 at the University of California, Santa Barbara (Hayward, Kogan, & Laursen, 2012). In each report, we shared workshop outcomes and formative feedback to the project team for use in planning subsequent workshops. This report serves as the final, cumulative report for all four workshops and provides a more detailed analysis from the combined data. We also report specific results from the 2013 workshop at the University of Chicago.

In this report, we describe the methods of data collection, and then share findings about who participated in the workshop, how satisfied they were with the workshops, and what changes they made to their teaching methods following the workshops. We also report findings from interviews we conducted with a subset of participants that provide context for survey findings and detail the factors that affected participants as they decided whether and how to implement IBL in their courses.

[3] At the Universities of Chicago, Michigan, Texas at Austin, and California-Santa Barbara.

Workshop Design

The project consisted of four intensive workshops held in the spring of each year from 2010 through 2013. While each four- or five-day workshop had its own unique schedule, they included similar activities such as talks from invited speakers and discussion panels. Participants at the different workshops engaged in activities such as watching videos, reading and discussing research articles, listening to plenary talks, participating in panel discussions with experienced IBL instructors, observing and discussing IBL classes, and developing IBL materials.

While all workshops used these strategies to varying degrees, each workshop had its own focus. In 2010, the workshop organizers most frequently used invited talks, hands-on exercises, and open discussions to help participants learn about IBL techniques. In 2011, the workshop was a conference style with invited talks and breakout sessions focusing on IBL in specific courses or about specific topics, such as assessment. The 2012 workshop split time roughly in half between full-group invited talks and working groups divided into calculus-track instructors and pre-service teacher instructors. In 2013, mornings were spent observing two sample classes and afternoons were filled with talks from experienced IBL practitioners. In general, the 2010 and 2012 workshops tended to be more active as participants engaged in discussions and developed materials, while the 2011 and 2013 workshops were conference-like and participants largely listened to talks.

Data Set

For the 2010 and 2012 workshops, registration and advertising were done in conjunction with the Mathematical Association of America (MAA) Professional Enhancement Program (PREP). The organizers of the 2011 and 2013 workshop handled registration themselves and invited many instructors from nearby institutions. Once participants registered for a workshop, they were asked to complete a brief survey on-line; a similar survey was administered in person on the final day of the workshop. A year after the workshops, participants were contacted to complete an online follow-up survey. All surveys included unique, anonymous identifiers that allowed us to match pre-, post-, and follow-up survey responses for each individual. The survey instruments are included in Appendix A.

The surveys included quantitative items and open-ended questions. Likert-scale items were developed to reflect participants' knowledge, skills, and beliefs about inquiry teaching, as well as their motivation to use inquiry methods and their perceptions of the overall quality of the workshop. For example, on both pre- and post-workshop surveys, participants assessed their current knowledge of IBL in math education on a scale of 1 to 4 (1=None, 2=A little, 3=Some, and 4=A lot). Open-ended questions addressed the costs and benefits of using inquiry strategies, participants' impressions and learning from the workshop, and how they planned to use that learning in their own educational activities. Participants reported personal and professional demographic information such as career stage, institution type, gender, race and ethnicity, so that we could explore possible differences in results. Some items were adapted from prior evaluations of faculty development by our group (ReSciPE, Resources for Scientists in Partnership with Education) and other items were developed based on discussion with workshop leaders about their goals and expectations for workshop attendees.

Additionally, follow-up interviews were conducted with a small subset of participants from the 2010 (7 participants) and 2011 workshops (9 participants). On the follow-up survey,

individuals were asked if they would be willing to take part in a telephone interview. Those who agreed were contacted and took part in approximately one-hour telephone interviews to gain deeper understanding of their development as instructors, their views on teaching and learning, and more detail about their classroom activities. The interview protocol is included in Appendix B.

The study design and instruments were approved by the CU Boulder Human Research Committee. An evaluator attended each of the workshops as a participant-observer, except for the 2011 workshop where a colleague kept detailed field notes for us. In addition, one author (SL) presented at and attended part of the 2010, 2011, and 2012 workshops.

Analysis Methods

For survey items, responses to numerical items were entered into the statistical analysis program SPSS (IBM Corp., 2012), where descriptive statistics were computed. Means and standard deviations were computed for some of the ratings items, and frequencies were computed for all of the items. Several participants left some items blank; these responses were omitted in the calculations. Pre-, post-, and follow-up responses were matched using unique identifiers, which allowed us to test for changes in each individual's responses (paired sample comparisons), not just changes in the overall group means. Open-ended responses were entered into MS Excel (Microsoft, 2011) and analyzed for trends based on the frequency of occurrence of common qualitative themes.

The interviews were transcribed verbatim and then analyzed for common themes using N'Vivo version 9 (QSR International Pty Ltd., 2010). Passages of interviews that referred to specific topics were coded for that topic; individual passages could refer to and be coded for more than one topic. Codes were developed both inductively, from the data, and deductively, from our prior knowledge of instructor development and implementation of inquiry-based learning. Codes that related to similar themes were grouped into larger domains. For a more detailed description of this process, please see reports of our previous interview studies (Laursen, Hunter, Seymour, Thiry, & Melton, 2010; Thiry & Laursen, 2009). In this study, we report frequencies in terms of both the number of participants' observations, or comments, within a category and the number of individuals raising a particular topic.

Because of the nature of semi-structured interviews (as opposed to the uniformity of survey questions), the numbers reported provide a measure of respondents' feedback, but are not statistically tested or generalizable. Questions are not asked in the same order or with the same wording in every interview, and some topics arise spontaneously and thus are not represented in every interview. Moreover, a low frequency does not necessarily reduce the importance of an observation—for example, an explanation given by a single individual may be particularly insightful in explaining and relating observations made by others. Thus, the numbers should not be used to make statistical inferences, but are nonetheless useful to indicate the general magnitude of trends.

Response Rates and Survey Matching

Overall, surveys had high response rates for all workshops. Rates were highest for the post-surveys, which were collected in person on the final day of each workshop. Response rates for each survey are presented in Table 1. Follow-up surveys for the 2013 cohort will be collected in the Fall of 2014.

Table 1. Response rates by workshop.

Workshop	*Attendees*	*Pre-surveys*		*Post-surveys*		*Follow-up surveys*	
		n	*%*	*n*	*%*	*n*	*%*
2010	42	37	88%	41	98%	31	75%
2011	55	47	85%	43	78%	36	65%
2012	42	40	95%	41	98%	29	69%
2013	28	22	79%	26	93%	--	--
Total	***167***	***146***	***87%***	***151***	***90%***	***96***	***69%***

On each of the three surveys, participants provided unique, anonymous identifiers that allowed us to match each individual's surveys without identifying who the surveys belonged to. Since some participants did not provide this information, we were not able to match every survey. Response rates for the matched samples are presented in Table 2.

Table 2. Survey matching.

Workshop	*Attendees*	*Pre-surveys*	*Post-surveys*		*Follow-up surveys*	
		n	*Total*	*Matched to Pre-*	*Total*	*Matched to Pre-*
2010	42	37	41	33 (80%)	31	23 (74%)
2011	55	47	43	29 (67%)	36	21 (58%)
2012	42	40	41	38 (93%)	29	25 (86%)
2013	28	22	26	21 (81%)	--	--
Total	***167***	***146***	***151***	***121 (80%)***	***96***	***69 (72%)***

Overall, these response rates are quite high and indicate that the findings are likely representative of the total population of workshop attendees.

Structure of the Report

Findings are presented in the following sections. First, we describe participants' personal and institutional demographics, as well as their pre-workshop teaching practices and goals. Then, we discuss their immediate post-workshop reactions, including their satisfaction with the workshop, their plans for implementing IBL, and their intent to participate in post-

workshop support activities. In the remainder of the report, we detail outcomes reported by participants one year after the workshops as we discuss participants' changes in beliefs about IBL, self-reported rates of implementation of IBL, and changes in teaching practices. Finally, we end with an in-depth analysis of participant interviews that highlights barriers and supports for IBL implementation, as well as the decisions, or considerations, instructors made as they implemented IBL in their courses. These interview findings offer a deeper understanding of the impact of the workshops and provide insight for future workshop designers about the important issues and topics they should cover.

Findings: Pre-workshop Surveys

On the pre-workshop survey, we sought to establish who the workshops were serving by detailing prior experience and background of the participants. In this section, we report results from items assessed only on the pre-workshop survey, including demographics, initial teaching practices, goals for students, and goals for the workshop. The pre-workshop survey also had participants self-assess their familiarity and skill with IBL teaching so that these could be compared with their self-assessment after the workshop. We report these latter comparisons in the section, Findings: Beliefs About IBL, on page 20.

Demographics

Demographic information was collected on the pre-surveys. Overall, pre-workshop survey respondents (N = 146) came from diverse institutional backgrounds and represented a variety of career stages. Personal demographics are presented in Table 3 and institutional demographics are presented in Table 4.

Table 3. Participant demographics.

Demographics		*n (146 total)*	*%*
Gender	Male	82	56%
	Female	59	40%
	Did not respond	5	3%
Ethnicity	European (or descent)	101	69%
	Asian-American	14	10%
	African-American	7	5%
	Middle Eastern (or descent)	6	4%
	Multiracial	4	3%
	Hispanic	3	2%
	Pacific Islander	1	1%
	Native American	0	0%
	Other	0	0%
	Did not respond	10	7%
Career stage	Tenure-track faculty, tenured	49	34%
	Tenure-track faculty, untenured	51	35%
	Non-tenure-track faculty	39	27%
	High school teacher	1	1%
	Graduate student	5	3%
	Other	1	1%
	Did not respond	0	0%
Teaching experience	< 2 years	29	20%
	2-5 years	40	27%
	6-10 years	28	19%
	11-20 years	26	18%
	>20 years	23	16%
	Did not respond	0	0%

Table 4. Participants' institutional demographics.

Demographics		*n (146 total)*	*%*
Institution type	Two-year college	6	4%
	Four-year college	53	36%
	Masters-granting comprehensive university	33	23%
	Ph.D.-granting research university	53	36%
	Did not respond	1	1%
Minority-Serving Institution	Yes	19	13%
	No	67	46%
	Don't know	58	40%
	Did not respond	2	1%

The only significant difference by workshop was for institution type. (There were no significant differences by workshop for personal demographics.) The 2013 workshop drew more participants from Ph.D.-granting research universities (64%) than the first three workshops (31%, 38%, and 25%, respectively). Minority-Serving Institution (MSI) is a federal designation for historically Black colleges and universities, Hispanic-serving institutions, and tribal colleges. Just 13% (19 individuals) identified their workplace as an MSI; many respondents (40%) did not know if their institution is classified as minority-serving. It is likely that faculty would be aware of MSI designation as a distinctive institutional characteristic, so we assume that most faculty are not at MSIs.

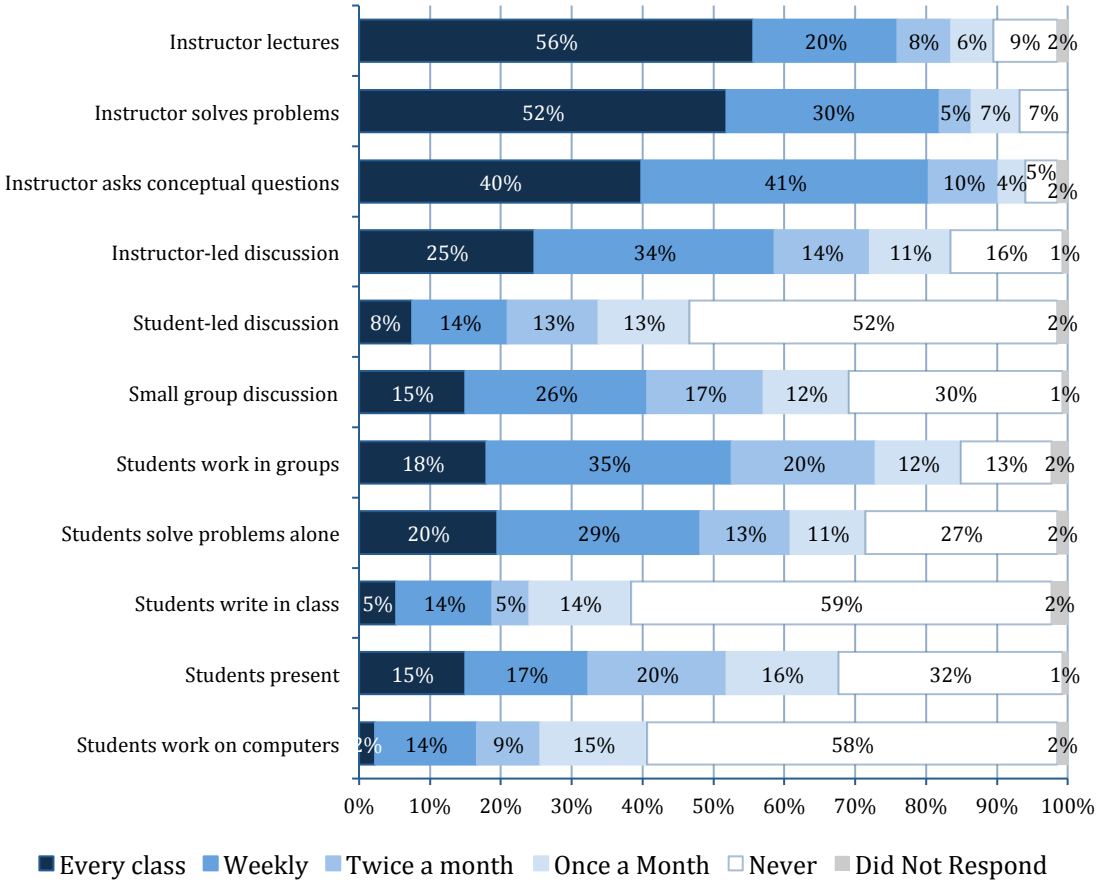
Some participants reported prior experience with IBL techniques, as 35 (24%) said they had taken an IBL class themselves and 65 (45%) had previously incorporated IBL techniques into their teaching methods. In total, 67 of the 146 respondents (46%) reported no prior experience with IBL as either a teacher or student.

The workshops had more male participants (56%) than female participants (40%). However, the percentage of women was about twice as high as math faculty at four-year colleges as a whole (National Science Foundation, 2008a). Most participants were of European descent (69%), with Asian descent (10%) being the second most common. The proportions of different ethnicities are about the same as in employed doctoral-level mathematicians and statisticians as a whole (National Science Foundation, 2008b).

Initial Teaching Practices

On the pre-workshop surveys, participants were asked to identify one specific course and rate the frequency of their use of various teaching practices in that course (never, about once a month, about twice a month, weekly, every class). Of the 146 pre-survey respondents, thirteen (9%) did not complete this section of the pre-survey and are excluded from the results, which are presented in Figure 1. 'Did not respond' indicates participants who completed this section of the survey, but did not respond to individual items.

Figure 1. Participants' initial teaching practices.



The most commonly reported strategies were traditional teaching methods: 56% of the respondents lectured in every class session, 52% solved problems on the board in each class, and 81% asked students conceptual questions leading to generalizations at least weekly. Student-centered teaching strategies were less common: 52% of respondents never used student-led discussions in their teaching, 32% never had students present problems or proofs, 59% never had students write in class, and 58% never used computers to aid learning.

However, many participants did say that they used some forms of active engagement in their courses at least once a week: 41% of respondents used small group discussion, 53%

used collaborative work in small groups, and 49% had students solve problems individually. Thus, while workshop participants' initial teaching practices were generally quite in line with traditional mathematics teaching, they also showed some signs of incorporating more active-learning methods. Teaching practices were measured again on the one-year follow-up survey and are compared to these initial practices later in the section, Findings: Changes in Teaching Practices. We did not attempt to assess the quality of implementation of these practices, only their use.

Participants' Goals for Students

With the single identified course in mind, attendees also ranked the importance of various goals for their students on a quantitative scale. Table 5 displays the responses to these questions in decreasing order by frequency of 'the most important' ratings. Participants ranked the importance of each goal individually, not in reference to the other goals.

Table 5. Goals for student learning.

Goal for students	*Not very important*	*Somewhat important*	*Quite important*	*The most important*
Thinking critically	2%	1%	36%	61%
Becoming more independent in problem-solving	1%	5%	44%	50%
Understanding mathematical concepts deeply	1%	13%	41%	45%
Developing skills in problem-solving	1%	8%	47%	44%
Gaining confidence in doing mathematics	3%	12%	44%	41%
Communicating mathematics in writing	1%	13%	58%	28%
Understanding the role of proof in mathematics	11%	29%	35%	25%
Communicating mathematics orally	4%	21%	51%	24%
Understanding the nature of mathematics	4%	27%	50%	19%
Appreciating the beauty or significance of mathematical ideas	5%	27%	50%	18%
Learning specific mathematical ideas	4%	26%	52%	18%
Applying mathematics to everyday life	24%	44%	23%	9%
Applying mathematics to other fields	20%	36%	36%	8%

The top goals relate to students becoming more independent mathematicians, while the lowest rated goals relate to specific mathematical concepts and applications.

Overall, workshop participants represented a variety of both personal and institutional demographics. While about half of participants had some prior experience with IBL, most

did not report using inquiry-based learning techniques. Participants' learning goals focused on the problem-solving and reasoning aspects of mathematics, but they did not always report using student-centered teaching strategies that are well suited to achieving those goals.

Findings: Post-Workshop Surveys

Throughout this section, we discuss participants' immediate reactions at the end of the workshops, while the three '*Findings*' sections after this report longer-term outcomes one year later. Post-workshop surveys were collected in person on paper forms on the final day of the workshops. In total, 151 participants (90%) completed the post-workshop survey, of which 121 (80%) were successfully matched to pre-surveys, for a net of 72% of participants matched. In this section on post-workshop findings, results from all 151 respondents are included, while some subsequent sections only use the matched surveys.

The post-workshop survey asked participants to respond to items about the quality of the workshop, their expectations for using IBL in their own classes, and concerns about implementing IBL. Results from these items are reported in this section. As on the pre-workshop survey, participants self-assessed their familiarity and skill with using IBL. The results of these comparisons are presented in the section, Findings: Beliefs About IBL.

Overall Satisfaction with the Workshop

Most participants rated the overall quality of the workshops highly. Most considered the workshop they attended 'excellent' (50%) or 'good' (43%) compared to other professional development workshops that they had attended. Participants rated the logistics of the workshop on the same scale. Many of the participants (46%) rated the logistics as 'excellent.' Full results for these two items are presented in Table 6.

Table 6. Satisfaction ratings.

	Workshop	*Poor*	*Below average*	*Fair or average*	*Good*	*Excellent*
Compared to other professional development workshops that you have attended, please rate the OVERALL quality of this workshop	2010	0%	0%	0%	13%	88%
	2011	0%	0%	8%	61%	32%
	2012	2%	0%	7%	59%	32%
	2013	0%	4%	8%	42%	46%
	Total	***1%***	***1%***	***6%***	***43%***	***50%***
Please rate the LOGISTICS (food, facilities, timing, length, breaks, etc.)	2010	0%	0%	5%	44%	51%
	2011	0%	5%	28%	42%	26%
	2012	0%	2%	2%	49%	46%
	2013	0%	4%	4%	24%	68%
	Total	***0%***	***3%***	***11%***	***42%***	***46%***

Between group differences were tested using the Kruskal-Wallis test. The test was highly significant for both overall quality ratings, $\chi^2(3, N=145)=32.1$, $p<0.001$ and logistics ratings,

$\chi^2(3, N=150)=17.8, p<0.001$. Follow-up Wilcoxon Rank-Sum tests were conducted to evaluate pairwise comparisons. These tests revealed that the ratings of overall quality for the 2010 workshop were significantly higher than the other three workshops, while those three workshops were not significantly different from each other. Logistics ratings were significantly lower for the 2011 workshop, and the other three workshops were not significantly different from each other.

In an open-ended item, participants were asked to explain their ratings. These open-ended comments have already been analyzed in detail in the three previous workshop reports. In general, participants provided varying feedback. For example, some really liked food options, while others commented that the food could be improved. The lack of general consensus shows no glaring problems with the workshop, and many of the suggestions may be a matter of personal preference.

For the 2013 workshop, there did seem to be some consensus. Of the 18 comments, eight commented on poor scheduling and the amount of wasted time at the workshop. Participants commented that sessions suffered from a lack of planning and felt they spent an "inordinate amount of time" observing demonstration classes that were not useful. As one participant explained, "My attention lapsed and I looked around and it appeared to me that many participants were not paying full attention after a while." Another commented that the logistics in general needed improvement, as, "There was no website for the conference, no schedule sent out, no hotel confirmation." Despite these complaints, participants still rated the overall quality and logistics of this workshop quite highly.

Likelihood of Implementation

Participants reported their likelihood of implementing IBL in the coming academic year, and if not this coming year, sometime in the future. Responses are reported in Table 7.

Table 7. Likelihood of implementing IBL.

Timeframe	*Did not respond*	*Not at all likely*	*Somewhat unlikely*	*Somewhat likely*	*Rather likely*	*Definitely*
In the coming academic year	3%	2%	3%	14%	30%	48%
If not this year, in a future year	29%	0%	1%	5%	19%	46%

Most participants (78%) reported that they would rather likely or definitely implement IBL in the year following the workshop, and more than half (65%) reported a high likelihood of implementing in the future, if not that year. Projected implementation rates did not differ significantly by workshop. Participants also provided some information about the classes in which they intended to implement IBL. Most frequently, they planned to use IBL with math majors (36% of responses) or mixed STEM majors (29%), in small classes of under 20 students (46%) or 20-35 students (43%), and with junior or senior students (45%).

While differences by workshop were not statistically significant, participants from the 2010 workshop intended to use IBL in smaller classes of mainly junior or senior math majors. Participants in other workshops reported greater variety in the types of courses where they intended to use IBL. This may be related to the strong tradition of the Moore Method at the

2010 host university, or to differences in content presented at the workshop. For example, the 2012 and 2013 workshops had sessions specifically about courses for pre-service teachers. At both of these workshops, 29% of participants intended to use IBL in pre-service teacher courses, while at the 2010 and 2011 workshops, it was only 5% and 20%, respectively.

Support and Keeping in Touch

On four items, participants reported their likelihood of participating in various post-workshop mentoring activities. Results are presented in Table 8.

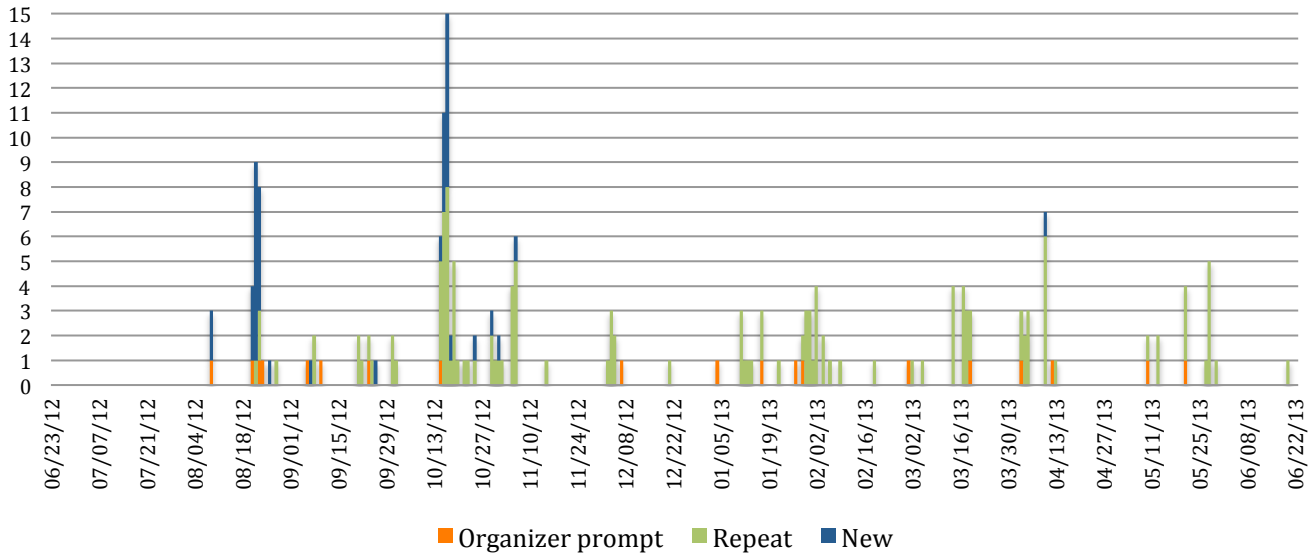
Table 8. Likelihood of participating in post-workshop mentoring activities.

Mentoring activity	*Not likely to participate*	*Somewhat likely to participate*	*Very likely to participate*
Email listserv for exchanging ideas and getting advice from other workshop participants & facilitators	9%	38%	53%
Email list for receiving articles, web links, and other resources from facilitators	7%	33%	61%
Web-based discussion board or chat room	34%	41%	25%
Occasional personal phone call or e-mail from facilitators	26%	39%	36%

Participants reported high likelihoods of participating in e-mail lists and occasional personal phone calls or e-mails, but less likelihood of participating in a web-based discussion board or chat room. For e-mail lists, participants reported that they were more likely to participate in a list where they receive resources from facilitators, rather than one for exchanging ideas with other participants as well as facilitators. This may be due to perceptions that the facilitators will give more expert advice than peers. Since both of these activities can be accomplished on the same list, it seems important that facilitators take an active role on the post-workshop e-mail list and that participants are free to engage when they see fit.

Despite stated plans to follow up with participants, in practice, only the 2012 workshop has actively done so. Facilitators established an e-mail list that included participants, facilitators, and staff from the workshop. It was quite active in the year following the workshop and the level of activity, distinguishing new voices from those who have previously posted to the list, is shown in Figure 2. Additionally, the figure highlights messages sent by workshop organizers specifically to encourage participation or check-ins from other participants.

Figure 2. Daily number of messages on 2012 workshop e-mail list.



In the year following the 2012 workshop, there were a total of 191 messages sent on the list. Of these, 19 were messages sent by organizers to prompt others to contribute. As evidenced in the figure, these often were followed by flurries of activity. Additionally, as discussions continued, new participants joined in. In fact, one list member did not send his first message to the group until 10 months after the workshop. By the end of the year following the workshop, 62% of workshop attendees and 65% of all members, including facilitators and staff, had sent at least one message to the list. Participants have used the list to check in and cheer each other on, as well as to share ideas and pose and respond to difficulties individual instructors were facing with implementing IBL in their classrooms. It appears that the list is a supportive and useful tool for many instructors.

Overall, immediate reactions to the workshops were positive; in most cases participants rated overall quality and logistics highly and many intended to implement IBL in their own courses, as well as participate in follow-up activities.

Findings: Beliefs About IBL

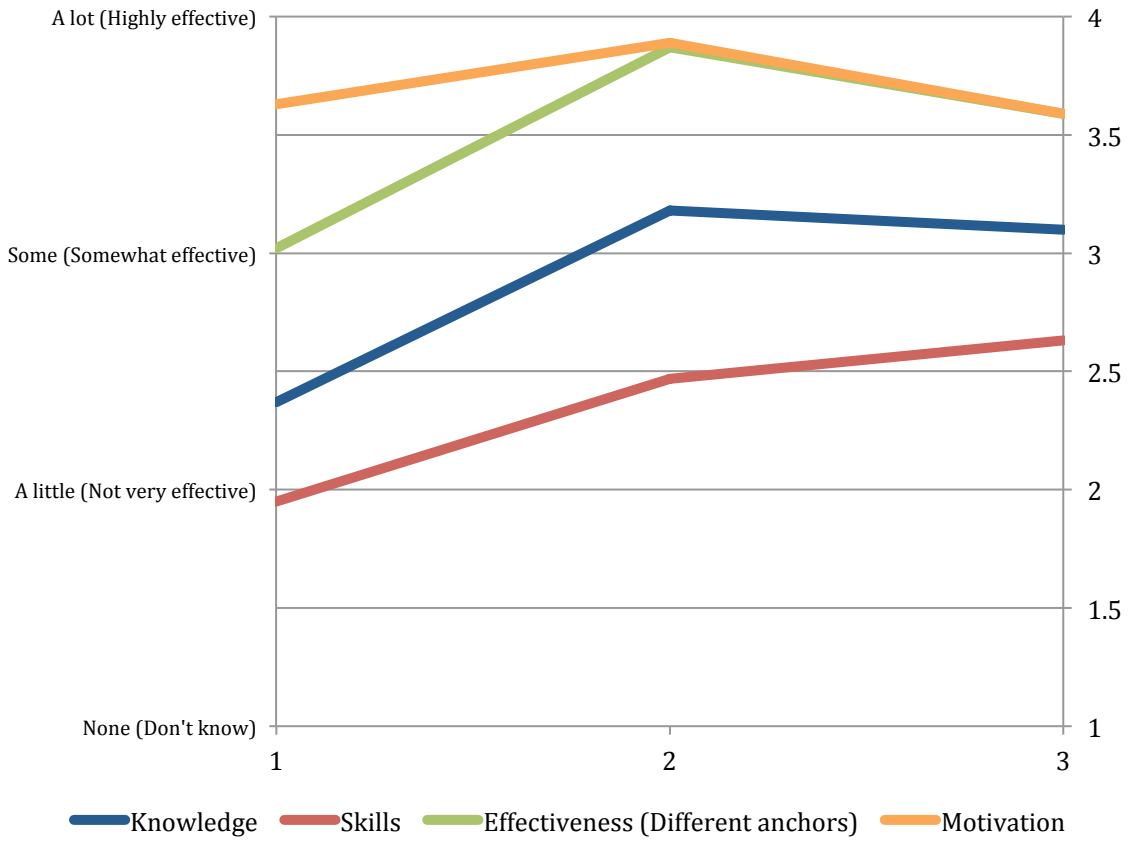
Here we begin to analyze the workshops' impact, starting with how participants' beliefs about IBL changed over time. Four items were assessed on pre-workshop, post-workshop, and one-year follow-up surveys. In these items, participants expressed strong beliefs in the value of inquiry strategies and high motivation to use inquiry-based methods in their own practice. In order to compare changes in beliefs over time, we analyzed responses for respondents who had completed all 3 surveys, which included 20 from the 2010 workshop (48% of participants), 18 from the 2011 workshop (33% of participants), and 25 (60% of participants). Table 9 shows the results of statistical comparisons and Figure 3 displays how respondents' beliefs shifted over time. There were significant differences by survey, but not by workshop.

Table 9. Immediate workshop outcomes.*

Survey item domain	*Survey*	*Frequency of response, by category*				*Mean (of 4)*	*Stat. signif. of differences*
		None	*A little*	*Some*	*A lot*		
Knowledge about IBL	*Pre*	9%	46%	42%	3%	*2.39*	F(2, 62)= 49.23 p<0.001
	Post	0%	8%	64%	24%	*3.17*	
	Follow-up	0%	9%	68%	23%	*3.14*	
Skill in inquiry-based teaching	*Pre*	26%	52%	21%	2%	*1.98*	F(2, 62)= 37.88 p<0.001
	Post	6%	44%	44%	5%	*2.48*	
	Follow-up	3%	35%	55%	8%	*2.67*	
		Don't know	*Not very effective*	*Somewhat effective*	*Highly effective*		
Belief in *effectiveness* of IBL	*Pre*	17%	0%	42%	41%	*3.08*	F(2, 62)= 34.55 p<0.001
	Post	0%	0%	14%	86%	*3.86*	
	Follow-up	2%	0%	33%	65%	*3.62*	
		Not at all	*A little bit*	*Somewhat motivated*	*Highly motivated*		
Motivation to use IBL	*Pre*	0%	3%	29%	68%	*3.65*	F(2, 62)= 10.43 p<0.001
	Post	0%	0%	11%	89%	*3.89*	
	Follow-up	0%	5%	29%	67%	*3.62*	

*Some rows may not add to 100% due to non-responses and/or rounding.

Figure 3. Participants' beliefs about IBL over time.



Knowledge About Inquiry-Based Learning

On the pre-workshop survey, most participants indicated knowing 'a little' (46%) or 'some' (42%) about IBL. Pairwise comparisons revealed that knowledge about inquiry-based learning rose significantly from pre-workshop to post-workshop survey, and stayed at that level one year later on the follow-up survey.

Skill in Inquiry-Based Teaching

Like knowledge about inquiry-based learning, skill in inquiry-based teaching also rose significantly from pre-workshop to post-workshop. On the pre-workshop, most participants report no skill (26%) or 'a little' (52%), but by the post-workshop survey, average responses rose by 0.5 on the four-point scale. Though scores were higher still by the one-year follow-up survey, the difference with post-workshop ratings was not significant.

Participants' reported inquiry-based teaching skills were lower than their reported IBL knowledge, and reported gains in teaching skills were less than gains in knowledge. This is understandable, since at the time of the post-workshop survey, attendees had not yet had a chance to practice the newly learned techniques.

Belief in Effectiveness of Inquiry Strategies

Participants entered the workshop with already strong beliefs in the effectiveness of IBL: 41% reported believing IBL is 'highly effective' and another 42% believed it is 'somewhat effective.' Attendees left the workshop even more persuaded: all respondents reported

believing IBL is either 'somewhat' or 'highly effective,' with 86% in the latter category. However, by the one-year follow-up, beliefs in effectiveness had fallen with only 65% believing it is 'highly effective' and 33% believing it is 'somewhat effective.' These follow-up ratings are still quite high, and higher than pre-workshop. It is possible that the immediate post-workshop ratings reflect the participants' excitement of new learning, which wears off slightly after the challenge of implementing the new techniques in their own classrooms.

Motivation to Use IBL

Participants' ratings of their motivation to use IBL follow a pattern similar to those of beliefs in effectiveness. Participants entered the workshops already motivated to use inquiry-based teaching, with 68% indicating that they were 'highly motivated.' This is not surprising for faculty who chose to attend a four-day IBL workshop. Motivation rose significantly post-workshop, but then returned to pre-workshop levels by the one-year follow-up. While these results suggest that the workshops did not have lasting effects on participants' motivation to use IBL, the participants were already quite motivated to start with. Additionally, the post-workshop spike in motivation may be instrumental in getting participants to start implementing IBL in their own classrooms, which will be discussed later in the section, Findings: Implementation of IBL**.**

Concerns About Implementing IBL

On both pre- and post-workshop surveys, participants reported their concerns about implementing IBL. Here, we compare pre- and post-workshop concerns as another way to evaluate how well the workshops met participants' needs. Full results are presented in Table 10 by decreasing number of concerns. The first two columns for each concern show the *total* number of comments expressing each theme on pre- and post-workshop surveys. (While an individual may have commented on multiple themes, each theme was coded at most once per survey.) The next three columns compare each individual's pre- and post-workshop responses. *Raised* concerns were not mentioned on their pre-workshop survey, but were on the post-workshop survey. *Dispelled* concerns were present on their pre-workshop survey, but no longer present post-workshop. *Lingering* concerns were reported on both pre- and post-workshop surveys.

Table 10. Comparison of pre- and post-workshop concerns.

Area of Concern	*Pre-workshop comments*	*Post-workshop comments*	*Individuals' Concerns*		
			Raised	*Dispelled*	*Lingering*
Harder to cover material	55	35	16	36	19
Student buy-in with IBL	33	47	35	21	12
Lack of skill to implement IBL	23	35	24	12	11
Not all students succeed with IBL methods	15	21	16	10	5
Increased time/workload	16	15	15	16	0
IBL not appropriate for all situations/courses	10	10	8	8	2
Relinquishing control of the classroom	7	9	6	4	3
Lower student evaluations	4	10	9	3	1
Resistance from colleagues	4	9	8	3	1
Difficult to find or make IBL appropriate materials	6	6	6	6	0
Totals	**173**	**197**	**143**	**119**	**54**
Average coded themes per participant[a]	1.43	1.48			

[a] Values corrected September 2014. Text changed in response.

Participants' concerns reveal some interesting trends. Prior to attending the workshops, coverage of material with IBL was the most common concern (55 comments). Coverage can become an issue when trading content breadth for depth, and as shown earlier, students understanding content deeply was one of the top goals for these participants. Therefore, coverage concerns may represent a conflict between participants' internal goals and external expectations. Comments supported this as participants mentioned feeling pressure to cover certain topics based on collegial expectations, standardized tests, subsequent courses, or requirements that science or engineering students be 'exposed' to certain computational techniques. A large number of these concerns were dispelled (36 individuals), while smaller numbers were raised (16 comments) or lingering (19 comments). This topic was often discussed at the workshops, yet remained a concern for many participants.

Concerns about student buy-in were also common on both surveys. However, on pre-surveys, participants seemed to worry about getting *any* students to buy in, while on post-surveys, participants seemed more concerned about getting *all* students to buy in. This may indicate increased confidence in their ability to get students to buy in, as workshops provided participants with strategies for explaining and marketing IBL to students. These concerns and strategies are discussed in more detail in the interview findings section, Considerations before or while implementing.

The third common concern, lack of skill to implement, makes sense on a pre-survey given that most were novice IBL practitioners. On post-workshop surveys, concerns about the difficulties of implementing IBL remained, but for the most part, participants were accepting and acknowledging these difficulties, rather than perceiving them as a reason not to implement IBL. The large number of concerns about skill that were raised or lingering following the workshop may indicate increased awareness rather than unmet needs. As participants gained more familiarity with IBL during the workshops, they may have also gained a better understanding of the challenges that come along with its use and the expectations for themselves as instructors. Indeed, a handful of participants made comments on the pre-survey to this effect, such as "[I'm] not familiar enough with it to have concerns." This trend is generally true for most concerns; all but two of the topics showed greater or equal numbers of concerns raised than concerns dispelled. Since a large number of concerns were dispelled (38% of all concerns) and few lingered (17% of all concerns), this suggests there were not many unmet needs. Despite the large number of concerns raised (45% of all concerns) on post-workshop surveys, the high rate of IBL implementation (discussed in the next section) suggests that this is due to increased awareness, as participants did not perceive the remaining concerns as great enough to deter them from using IBL.

These three main concerns were important topics in the workshops. While facilitators did share strategies for dealing with coverage and buy-in issues directly, these concerns also likely dissipate over time as instructors practice and gain skill with IBL. In fact, participants did report gains in knowledge and skills following the workshops, and the framing of concerns shifted from anxiety to awareness. We suggest that participants' concerns diminished in magnitude from impenetrable barriers to manageable hurdles, a process that may continue as participants gain more experience with IBL.

Findings: Implementation of IBL

In the next sections, we discuss rates of implementation and offer details of what implementation meant in terms of actual teaching practices reported on the surveys and in interviews. Then, we end by analyzing interview data on factors that affected implementation.

On one-year follow-up surveys, participants indicated whether or not they had implemented IBL in any of their classes. Item response choices reflect the way IBL practitioners talk about using IBL as the primary method of instruction ('full IBL') or incorporating inquiry-based methods in combination with more traditional instructional strategies ('partial IBL'). Results are presented in the two figures below. Figure 4 shows results for all 139 participants from the first three workshops for which follow-up surveys have been collected, including those who did not respond to the follow-up survey. This represents a conservative estimate of at least 58% of all participants using at least some IBL methods in their classrooms in just the first year following the workshop. Given that transitioning to IBL takes time to plan a new course (as evidenced later in findings from the interviews), this is quite a high rate of uptake.

Figure 4. Implementation of IBL methods after one academic year, all 2010-12 participants.

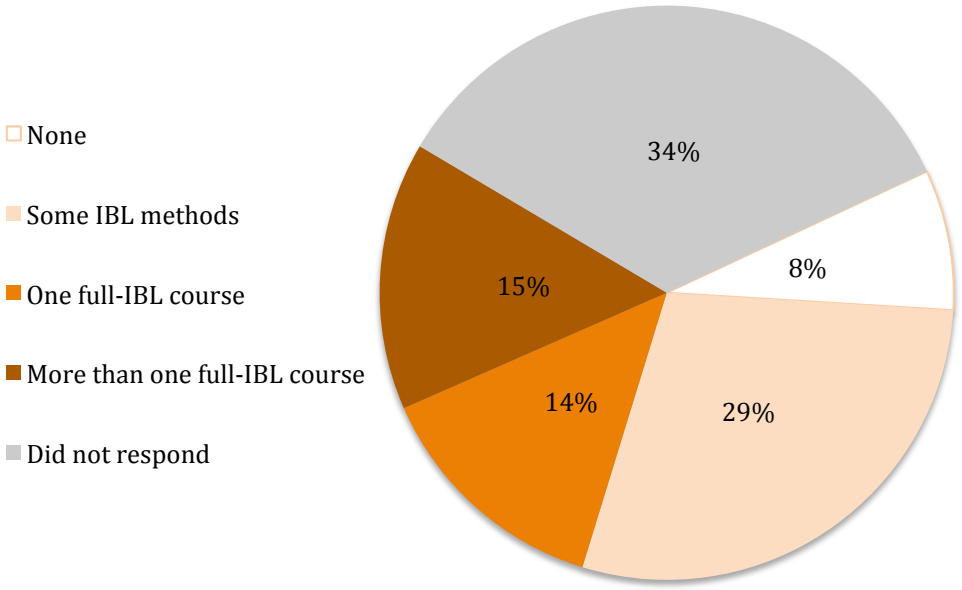
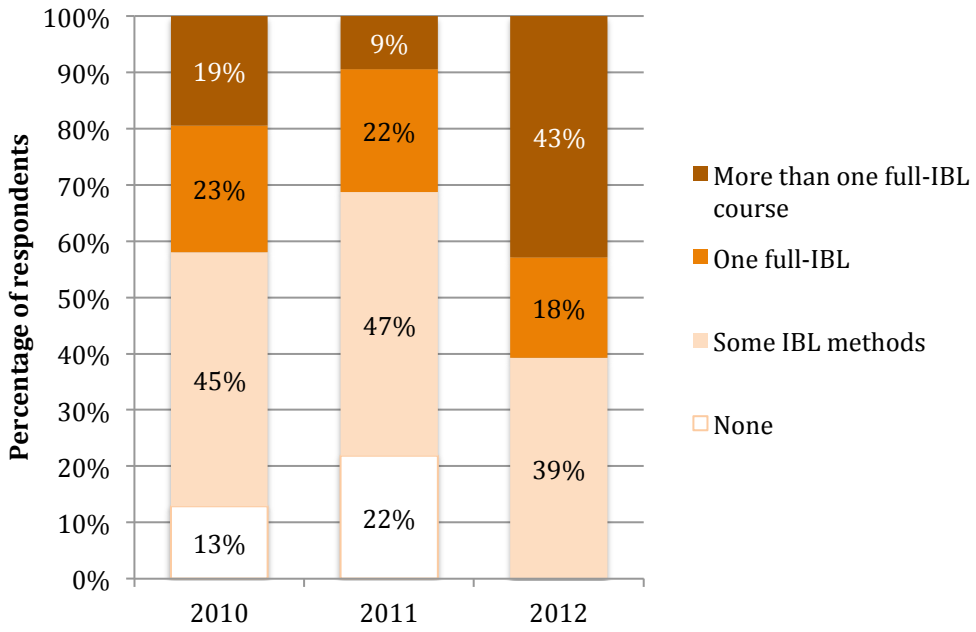


Figure 5 shows implementation levels for only those who responded to this question (31 of 42 in 2010, 74%; 32 of 55 in 2011, 58%; and 28 of 42 in 2012, 67%). The differences between workshops were statistically significant, χ^2 (6, 91)=13.87, p<0.05. Pairwise comparisons revealed that implementation rates for the 2012 workshop were significantly higher than the 2010 and 2011 workshops, which did not themselves differ significantly. This may be related to the increased follow-up and e-mail mentoring provided to the 2012 cohort, which we have already discussed and presented in Figure 2.

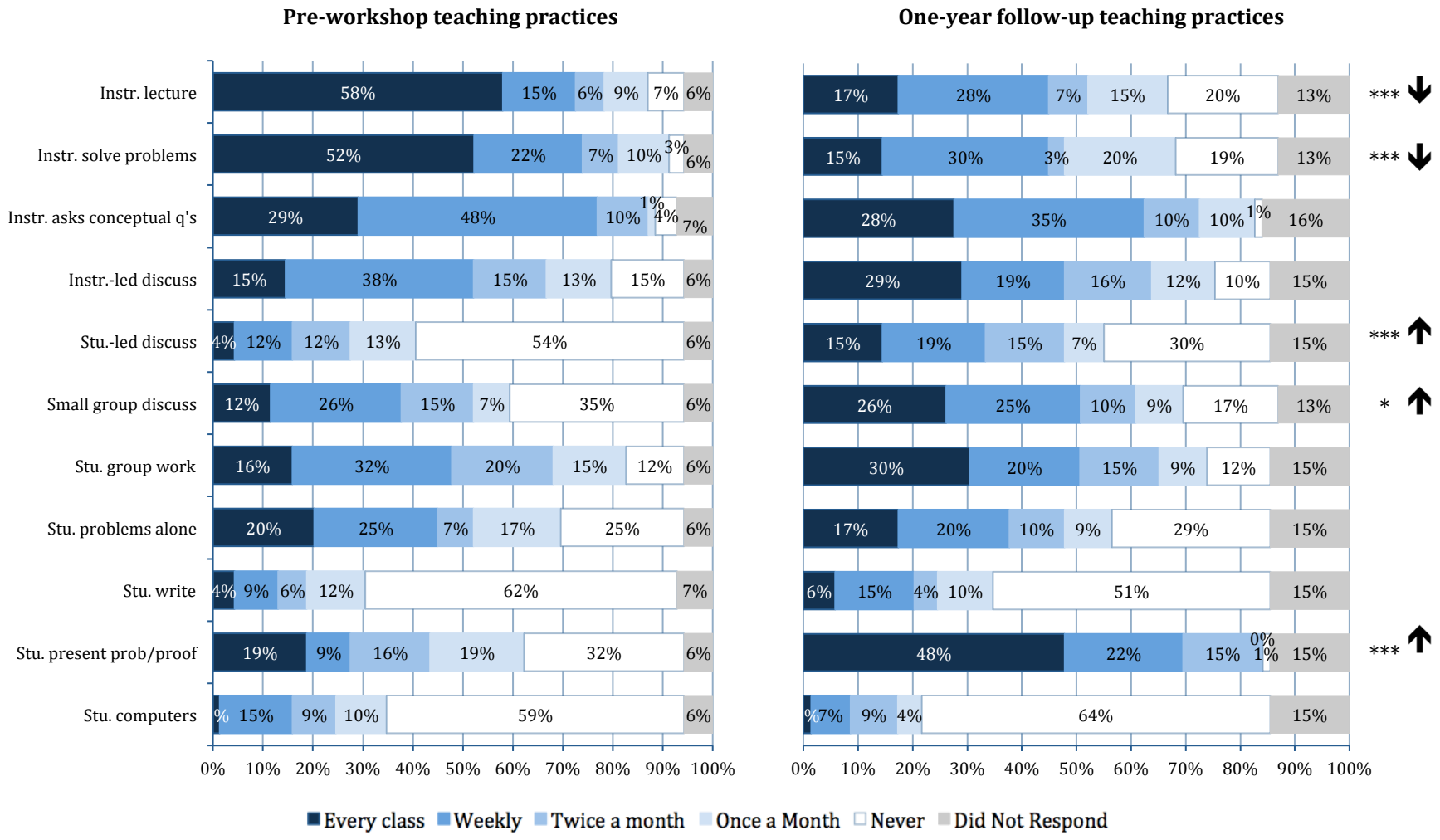
Figure 5. Implementation of IBL methods by one-year follow-up survey respondents.



Findings: Changes in Teaching Practices

In addition to rating their level of IBL implementation, participants also reported their current teaching practices on the follow-up survey using the same items as on the pre-workshop survey. Follow-up surveys were conducted for the first three workshop cohorts. Of the 139 participants in the first three workshops, 96 (69%) responded to the follow-up survey and 69 (71%) of those were matched to pre-workshop survey responses. In Figure 6 below, pre-workshop teaching practices are compared to one-year follow-up teaching practices for the 69 respondents with matched pre-workshop and follow-up surveys. Significant differences in these ratings are indicated by asterisks and by ↑ indicating increased frequency of the practice and ↓ indicating decreased frequency.

Figure 6. Pre-workshop and one-year follow-up teaching practices comparison, matched responses only.



*p<0.05, **p<0.01, ***p<0.001

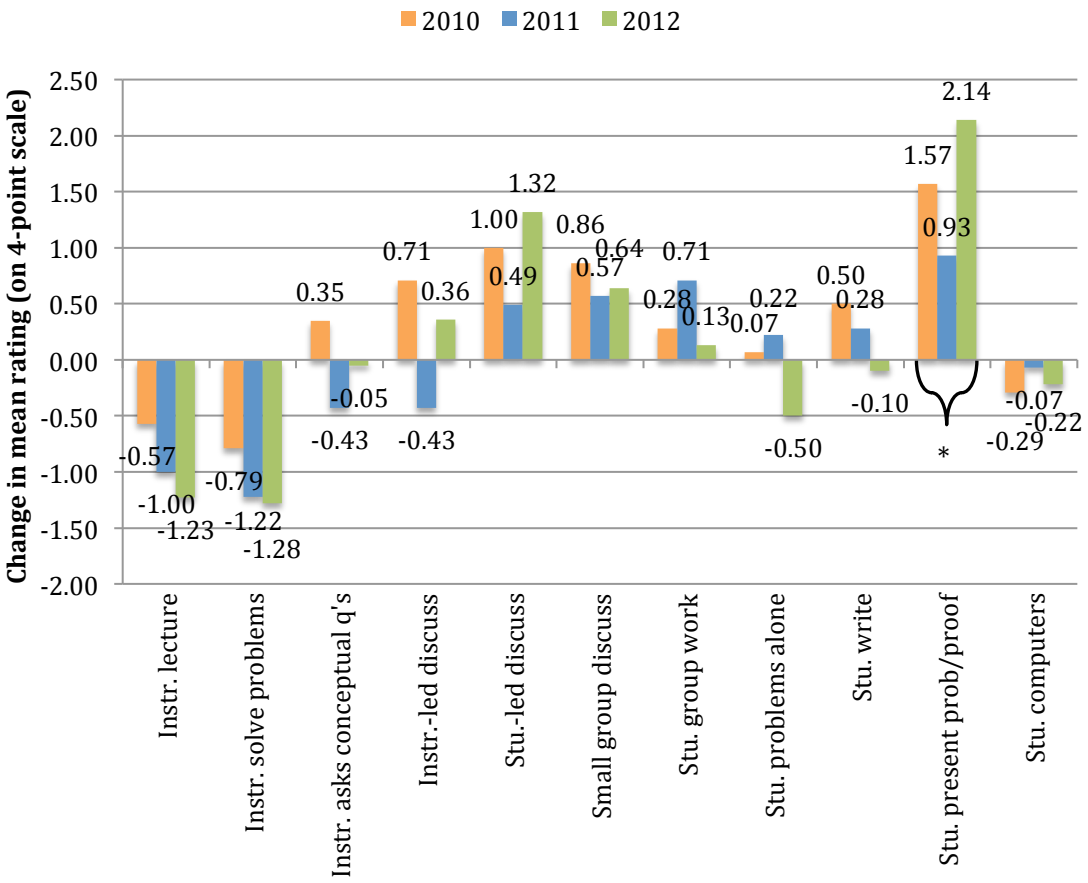
We tested for differences in the mean change in individuals' teaching practices using Wilcoxon Signed Ranks tests, which revealed the significant changes detailed below in Table 11. Other items did not differ significantly from pre-workshop to one-year follow-up. Ratings are on a 5-point scale with 1= 'never,' 2= 'about once a month,' 3= 'about twice a month,' 4= 'weekly,' and 5= 'every class.'

Table 11. Significant changes in teaching practices, pre-workshop to one-year follow-up.

	Teaching practice	*Pre-workshop median rating*	*One-year follow-up median rating*	*Increased ratings*	*Decreased ratings*	*Unchanged ratings*	*Z,p*
Increased frequencies	Student-led whole group discussions	1.0	3.0	29	8	18	*-3.81, p<0.001*
	Student small group discussions	3.0	4.0	33	9	14	*-2.92, p<0.01*
	Student-led presentations of problems or proofs	2.0	5.0	39	3	13	*-5.27, p<0.001*
Decreased frequencies	Instructor lecture	5.0	4.0	7	31	18	*-3.84, p<0.001*
	Instructor solving problems or examples on the board	5.0	4.0	3	33	20	*-4.33, p<0.001*

Additionally, we tested for differences in changes in teaching practice by workshop. There was a significant interaction of survey-by-workshop for student-led presentations of problems or proofs, $F(2, 50)=3.34$, $p<0.05$. No other teaching practices had significant survey-by-workshop interactions. The effect sizes of changes in teaching practices from pre-workshop to one-year follow-up are presented in Figure 7.

Figure 7. Change in mean rating of teaching practices from pre-workshop to one-year follow-up, by workshop.



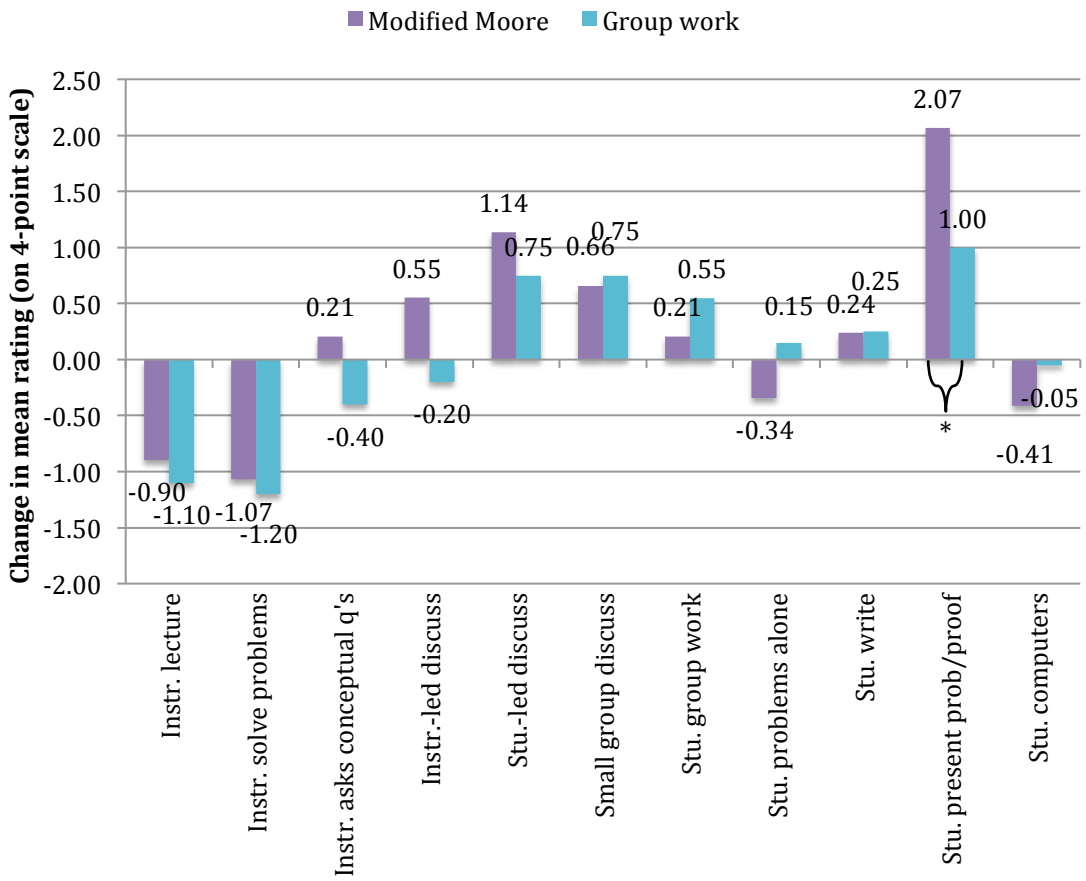
*p<0.05, **p<0.01, ***p<0.001

The interaction of survey-by-workshop for student presentations is interesting given how the workshops presented IBL. The 2010 workshop presented IBL mainly in the form of Modified Moore Method, which relies heavily on student-led presentations of problems or proofs followed by group discussion, while the 2011 workshop presented a version of IBL relying mainly on collaborative small group activities. The 2012 workshop, however, was divided into two different working groups. The working group for calculus-track instructors presented a version of IBL closer to a Modified Moore Method, while the other working group for instructors of pre-service teachers used collaborative small group work. We asked participants from the 2012 workshop to identify which group they attended during the workshop so that we could analyze for differences based on how the workshops presented IBL. We grouped the 2012 participants with the appropriate participants from the 2010 and 2011 workshops.

Of the 69 participants with matched pre-workshop and one-year follow-up surveys, 39 received a Modified Moore Method presentation of IBL (23 from the 2010 workshop and 16 from the 2012 workshop) and 29 of them completed the survey. Additionally, 29 participants received a collaborative small group work presentation of IBL (21 from the

2011 workshop and 8 from the 2012 workshop) and 20 of them completed the survey. One participant from the 2012 workshop reported attending both working groups about equally, and was not included in these results. The only significant difference was that participants who had seen a Modified Moore Method presentation of IBL (n=29) reported a greater increase in the frequency of student presentations in their course than those who had seen a collaborative small group work presentation of IBL (n=20), ($F(1, 47)=5.79$, $p<0.05$). Full results are presented in Figure 8.

Figure 8. Change in mean frequency of teaching practices from pre-workshop to one-year follow-up, by type of IBL presented at workshop.



*$p<0.05$, **$p<0.01$, ***$p<0.001$

When all comparisons are taken together, these changes in teaching practices indicate that regardless of the type of IBL presented at the workshop, participants reported making some common changes to their classroom practices. These included decreases in the instructor-led activities of lecturing and solving problems on the board and increases in the student-led activities of whole group discussions, small group discussions, and presentations of problems or proofs. However, the increases in student presentations of problems or proofs were higher for those participants exposed to a Modified Moore Method representation of IBL. These shifts suggest that following IBL workshops, participants' classrooms are moving away from traditional instructor-centered lectures to more active, student-centered

discussions and presentations. These findings are limited by small sample sizes—despite the high response rates, each workshop cohort is not large, nor are survey samples complete. Moreover, whether instructor self-report of this type is accurate is a question of high interest in current research. Triangulation with interview data in the next section provides some support for the validity of these self-reported changes. Additionally, our group is currently working on another NSF-sponsored study (*DUE*-1245436) to validate self-reported teaching practices with classroom observations.

Participant Interviews

Data

Follow-up interviews were conducted with a subset of participants who had indicated willingness to participate in an interview. In total, seven participants from the 2010 workshop and nine participants from the 2011 workshop were interviewed. Interview questions aimed to elicit more detail about instructors' classroom practices, as well as their history with IBL. Demographic classifications for the interviewees are presented below in Table 12 and indicate that interview participants were representative of the larger sample.

Table 12. Demographics of interview participants.

Demographics		*n (16 total)*	*%*
Gender	Male	7	44%
	Female	9	56%
Career stage	Tenure-track faculty, tenured	7	44%
	Tenure-track faculty, untenured	8	50%
	Non-tenure-track faculty	1	6%
Teaching experience	2-5 years	8	50%
	6-10 years	3	19%
	11-20 years	4	25%
	>20 years	1	6%
Self-reported IBL implementation level	Non-implementer	1	6%
	Some IBL methods	8	50%
	One full-IBL course	3	19%
	More than one full-IBL course	4	25%

Findings: Classroom Practices

In each interview, participants were asked to elaborate on the classroom practices they had described on the survey, both to validate self-reported implementation levels and to gain deeper insight into their classroom practices. In the next three sections, we present broad descriptions of the classroom practices of each of these groups of participants. In general, the descriptions are consistent with the self-identified implementation levels and provide

some confidence in the validity of the self-report survey, as well as a more nuanced view of the classroom practices of these workshop participants.

Non-implementer classroom practices

One interviewee described his or herself as a 'non-implementer' and described her classroom activities as, "Straight up, pretty conventional lecture," and, "I do a lot of talking in that class." This instructor did not use any forms of student presentation or group work.

Partial implementer classroom practices

Of the 16 interviewees, eight (50%) characterized themselves as implementing 'some IBL methods' rather than 'a full-IBL course.' These partial implementers described using IBL methods in different ways. Some described largely lecture-based courses with lots of student interaction. One participant described this style of 'interactive lecture' as, "I ask students to speak up and problem-solve in class, but they are not necessarily coming to the board."

Others went a little further on the IBL spectrum and used a blended approach of lecture with some elements of group work or student presentations. Some used IBL methods infrequently, such as one participant who said, "Occasionally I would give out worksheets that the students would work on in groups, but the majority of the information came across through lecture." Other participants used IBL methods almost daily. For example, one participant used IBL methods for part of each class, explaining that, "If it's a 50-minute class, there will be 15 to 20 minutes of [student] presentation, 15 to 20 minutes of lecture and then 10 to 20 minutes of the group activity." Another participant reported her course as fully student-centered during some class sessions, and described it as, "We met three days a week. I would probably lecture a half of two days. So lecture a little bit on one day and then have them work. Lecture a little bit on another day and have them work, and then the third day it was all them."

Some participants also described lecture-based courses with certain topics that they did not lecture on and students were responsible for learning themselves. For example, one instructor said,

> *The way I tried to integrate IBL techniques was that I would purposely not talk about certain concepts in the material, and then have the class working on projects or individual homework assignments or group work in the classroom, where they'd have to study the material and learn it on their own and teach each other and develop their own ideas.*

Another partial-IBL approach involved a slow transition over the course of the semester from lecture-based to full-IBL, explained as,

> *In the beginning of my semester, in my class, it will be lecture style. Mostly I will be introducing definitions and talking a little about how these things are related to each other, so I'll be lecturing quite a bit for the first, let's say, two weeks. After that initial two weeks I will slowly begin to step back and lecture less and have the students discuss with each more until at the very end of the semester I will write up the problem on the board, and I will suggest that they may want to consider these definitions when thinking about it and just leave them be for the rest of the hour.*

While these various descriptions of partial implementation of IBL are quite different from each other, and may not all constitute genuine inquiry, they represent examples along the

spectrum from an instructor-centered and lecture-based course to a student-centered and inquiry-based course.

Full implementer classroom practices

Seven of the 16 interviewees (44%) indicated that they had fully implemented IBL methods. Of these, three reported using "full" IBL in one course, and four reported using "full" IBL in more than one course.

These full-IBL implementers descriptions focused on students actively doing mathematics. For example, one instructor characterized a normal day in class as:

> *The first thing we do is we organize who thinks they have what problem that they would like to present today. I normally give them out in small chunks, like they'll have 5 or 8 problems that I expect them to do by the end of next week or something. Normally I hope to get through 3 problems a day. And we make a list on the board of who's gonna present what, and they go up and they try and present their ideas and their work and defend it. Then they take questions and they listen to comments, and we discuss technique and possible failings and how things all fit together. And we just discuss as a class.*

Putting responsibility on the students for figuring out the mathematics was a common theme with the full-IBL implementers. One instructor explained how this was accomplished with a change in approach to group work:

> *When I'm teaching something that's IBL, I don't answer questions, or I'm more hesitant to answer questions. Whereas if students [in my other courses] are turning in group work projects, I'm more likely to answer any question a student would have.*

Another instructor also described taking a different role, largely just to guide discussions:

> *Well, actually, what I do is a whole lot of nothing, is what it looks like. I really do just give them things to work on and then go sit in the back. And as the conversation develops, I guide it and nurture it and I encourage and cajole. And when it's necessary, I get up and spend 10 minutes providing context and maybe setting new questions or refining something that someone else has asked.*

Many of these full-IBL implementers described still using lectures occasionally. In addition to providing context for students' presentations, these next two instructors demonstrated other circumstances where quick 'mini-lectures' were still useful, such as to tie together work the students have done:

> *In Topology, I wanted to get through the fundamental group because we were sort of—we were building up to it and we had gotten to covering spaces. They had kind of worked out a lot of results up to there, and there was like this little push that we needed to get through…. I wanted them to have that big-picture result, to be able to just develop the whole, broad view of what was going on, and how all the little, nitty-gritty details that they had worked out, how those actually combined to form part of some bigger theory.*

Another example occurred when there was more material to cover than an in-depth IBL approach will allow:

> *It was sort of this case where the class sort of determines the pace. We had only five students in this class, and so when we're getting to some of the harder material that led up to the fundamental group, things started getting slower and slower and slower. Then I blinked and suddenly the end of the semester's in two weeks. If we're gonna get through this material, I had to change something. Then I did some lecturing.*

In general, participants' descriptions of classroom practices were in line with their self-identified implementation level for all three categories, and revealed that they saw IBL as not necessarily one specific method, but a spectrum of methods sharing a common theme of student-driven inquiry.

Findings: IBL Implementation Factors

Interviewees also spoke about the factors that had both helped and prevented or slowed their implementation of IBL methods. We have organized comments in the next three sections as barriers to implementations, supports for implementation, and considerations before or while implementing. 'Barriers' and 'considerations' are generally differentiated by whether the factors were problems that instructors encountered when implementing or trying to implement IBL (barriers) or were merely issues to be conscientious about while implementing (considerations); some factors are discussed in both sections based on how participants discussed the issue. These comments provide some insight into the factors that professional developers may want to address during workshops in order to help participants avoid potential pitfalls and build supports.

Barriers to implementation

Participants spoke about problems they had encountered when trying to implement IBL techniques. For some, these were barriers they had to overcome before implementing IBL, but for others, these were problems that they experienced while implementing IBL. In all, 15 of the 16 participants made a combined 96 comments about barriers. These barriers are listed in Table 13 by decreasing number of comments.

Table 13. Barriers to implementation of IBL.

Barrier	*# of interviewees*	*# of comments*
Student resistance	12	22
Instructor fears	9	18
Tenure/evaluations	8	11
Shy students	7	11
Lower-level or unprepared students	5	10
Designated curricula (coverage)	6	9
Students do not do the work	6	9
IBL doesn't work for all students	4	4
Students don't learn procedures	2	2

The most common of these concerns, Student resistance, was discussed at the workshops but continued to be an issue as participants implemented IBL in their classrooms. For example, on the 2012 follow-up listserv, there were at least 8 separate threads mentioning 'resistance.' Workshops gave instructors strategies to be proactive in avoiding student resistance, largely through positive messaging at the beginning of, and throughout, the course. This proactive approach was important, as one instructor explained, "I didn't put in enough ground work that first month, of selling—so that in the end, I had to somehow do a lot of damage control." Another elaborated on how, if not addressed, student resistance could lead to a class 'mutiny':

> *When students are creating the math and they're doing the IBL presentations, and they don't give a presentation that's as polished or as informative or as nicely framed as someone with a PhD in mathematics would've given, that doesn't make the person that gave the presentation feel good. [And then] they have this question, "Why don't you just lecture? I succeeded with the lecture model."*

Interviewees mentioned student resistance may come from a variety of sources, such as a mismatch between students' computational approach to mathematics and IBL's more conceptual approach, or discomfort with techniques different than what they are accustomed to. Some instructors mentioned that students can be afraid of IBL because it makes their understanding—or lack of it—more transparent to their fellow students. For example:

> *[Students] are so desperate to not be wrong that they don't want to try as hard…. Some of my students are uncomfortable with not having, say, a sample calculation that they can look at and replicate and do until they get comfortable and then try to build some understanding off of that.*

Instructors also mentioned their own fears. These included being more comfortable lecturing, being afraid that their IBL class would not be 'perfect,' and not wanting to relinquish control as their classes shifted to more student-centered activities. Particularly for newer instructors, student evaluations were a concern. Specifically, instructors were

worried that student resistance may lead to lower evaluations and in turn, affect their chances of receiving tenure.

Another common theme was students who do not excel in IBL classrooms. Some interviewees mentioned that IBL just did not work for some students (4 comments), while other instructors specified that it did not work for shy students who were unwilling to present (11 comments), students who were mathematically unprepared for the course of just behind their peers (10 comments), or students who are not willing to put in the extra work required by IBL (9 comments). Instructors were hesitant to implement IBL when they anticipated that certain students would be left behind.

The final two barriers, designated curricula (9 comments) and students not learning procedures (2 comments), both deal with student learning. Some instructors felt pressure from their departments to cover a certain amount of content in their courses, especially when those courses served as prerequisites to other courses. These instructors felt that IBL's in-depth approach slowed down the pace of the course and reduced the breadth of content that could be covered. Another instructor commented that learning certain procedures was important for science and engineering majors in one course and the IBL materials he found "didn't really deal with all of the different applications that I needed it to deal with, so I felt like I couldn't use this as a linear algebra course without shortchanging many of the students who have it as a requirement because of outside fields."

While interviewees shared barriers to implementation, it should be noted that of the 16 interviewees, 15 of them were implementing IBL to some degree. So while these may have initially been barriers, these instructors were largely able to overcome them and still implement IBL techniques. This highlights the importance of workshops providing techniques and strategies for participants to overcome these common barriers. Moreover, the barriers identified in the interviews were generally consistent with concerns mentioned on surveys. The related issues of student resistance and buy-in were at the top of both lists, and suggest that this is a central issue for novice IBL implementers. Future workshops should continue to provide participants with strategies to build student buy-in and respond to student resistance.

Supports for implementation

In addition to barriers, participants also identified factors that had supported their implementation of IBL techniques. The 16 interviewees commented on supports a total of 126 times. These are listed in Table 14 by decreasing number of comments.

Table 14. Supports for implementation of IBL.

Support	*# of interviewees*	*# of comments*
Departmental support	16	45
Additional professional development	15	38
Mentors/IBL colleagues	12	34
AIBL mini-grants	4	9

Departmental support was key for participants implementing IBL. Some participants described a general departmental freedom or openness to experimenting with new teaching

practices and styles, while others described specific support for IBL techniques. Having other IBL practitioners in a department was helpful because students were less resistant when they were used to "a real emphasis on communication and thinking and explaining that starts day one, freshman year. That really helps a lot. They're expecting that from their math classes." One instructor even described how the department chair protected him from student resistance that "comes out on faculty evaluations, and it does make a difference here. [Evaluations are] the strongest point for tenure and for promotion, and so it has affected actually what my chair assigns to me as courses because he's trying to protect me at times."

On follow-up surveys, respondents rated the support they felt from various colleagues. In general, participants indicated supportive colleagues. In total, most respondents reported 'mixed or moderate support' or 'mostly supportive' for their departmental colleagues (90%), department chairs (89%), deans or provosts (85%), and colleagues outside of their departments (84%). These ratings did not vary based on the level of implementation participants reported.

Additional professional development activities related to IBL included observations of others' IBL classrooms (4 interviewees), and participating in the IBL-focused 'Legacy of R.L. Moore' conference (4 interviewees) or Project NExT (4 interviewees). Others also mentioned attending some IBL talks at the Joint Mathematics Meetings or regional MAA meetings, though these larger meetings were not necessarily IBL-focused. Interview participants mentioned being exposed to IBL in multiple ways before they finally began implementing it in their classrooms. For example, one participant explained how prior experiences led to his participation in this IBL workshop:

> *I first heard about [IBL] through Project NExT and that was during a time when I was actively thinking about trying to make an effort to become a better instructor and looking for some way to do it. I heard about [IBL] through there and got an invitation to come down to the Legacy of R.L. Moore conference…. [The Legacy Conference] was rather rapid and I felt like I needed to learn some more about how to do [IBL] the right way. I was especially looking for information on how to go about the details of putting together a sequence of tasks. And that's actually something that we spent time at during this workshop.*

Another common theme was having a mentor or IBL colleague to work with. Some of the workshop organizers and presenters were commonly mentioned as helpful mentors, including Carol Schumacher, Michael Starbird, and Stan Yoshinobu. Interviewees cited conversations with these individuals, books and materials they wrote, and talks they gave as useful developmental activities. The recurrence of their names in interviews indicates that these individuals are central to the national IBL community. In fact, these three were mentioned 96 times throughout the 16 interviews. Some participants also developed more localized communities with IBL practitioners from nearby institutions. One participant explained:

> *Basically, we started a dinner series this semester, sort of regional discussions about inquiry-based learning. We met before the semester started, two weeks in, two weeks after that, and then since then it's been once a month to chat about different things and to share books, to discuss stuff. There's one person who just started using it this semester, and I went and watched one of his classes and gave a few comments.*

Another part of the IBL community is the Academy of Inquiry-Based Learning, which, among other activities, provides mini-grants for instructors to help them implement IBL. Four of the participants had received these grants, which they used to develop materials for IBL courses.

Considerations before or while implementing

The most common implementation factors that participants noted were not necessarily barriers or supports, but simply things to consider when implementing IBL. In total, all 16 participants commented a total of 417 times on these factors, reflecting their growing awareness of issues and sophistication in managing them. Common themes are listed in Table 15 by decreasing number of comments.

Table 15. Considerations for implementing IBL.

Consideration	*# of interviewees*	*# of comments*
IBL-appropriate course materials	16	62
Changing of instructor's role	9	43
Class level	15	39
Techniques for student participation	12	34
Assessment	15	30
Coverage (depth vs. breadth)	10	29
Class size	15	28
Other effects (Planning, time, office hours)	14	23
Student audience	12	22
Student buy-in	11	22
Marketing	13	21
Conceptual vs. computational	8	21
Changing of students' roles	7	16
Pre-service teachers	6	12
More dynamic classroom	6	8
Physical space	4	7

These considerations fell into three broad groups: IBL tools, identity considerations, and situational factors. We discuss each group below.

'IBL tools' were comments related to techniques, strategies, and materials used to implement IBL successfully. The most common consideration, IBL-appropriate course materials (62 comments), is included in this group and refers to comments interviewees made about finding or developing class scripts or materials that were appropriate for an IBL approach. IBL-specific materials are necessary to help thoughtfully guide students through an inquiry process without doing the intellectual work for the students, as most traditional textbooks do. Participants mentioned developing their own class notes, borrowing and

modifying notes from other IBL practitioners, using IBL-specific textbooks, and downloading class notes from the online database, *Journal of Inquiry-Based Learning in Mathematics.*

Techniques for fostering student participation were another tool that interviewees commonly mentioned (34 comments). Since students are largely passive during traditional lectures, the prevalence of comments about student participation indicates a stark contrast between lecture and IBL. Instructors had developed a number of strategies to encourage broad participation from all students. Some used computers to keep track of student contributions and give equal opportunities to all students, and some mentioned forming groups specifically to encourage students to interact with a wider variety of classmates beyond those they usually sat near.

Instructors also gave incentives for class participation by including it as part of students' grades, so assessment practices serve as another IBL tool. Indeed, assessment practices in IBL were different than traditional homework and exam grades in lecture model classes. Interviewees made 30 comments about assessment, and described various practices to assess group work, student presentations, take-home exams, group homework, and student portfolios. While instructors had their own individual strategies, they were each designed to meet the goals of the instructor. For example, one instructor explained, "Each student, I'm expecting them to be up at the board. The grade demands that they need to be going up to the board five times throughout the course of the semester." Another instructor felt that IBL provided more opportunities to assess students and provide them with feedback:

> *As compared to complete lecture-based, or traditional lecture, it just more naturally provides a learning environment where the faculty member can conduct formal or informal assessment on what their students are thinking, and I think that's a big thing. When they're going to the board and you're reading their proof or you can ask them questions or whatever, you just naturally get insight into how they're understanding it.*

Interview participants also mentioned student buy-in frequently (22 comments). While participants were concerned about this issue, several also described examples of things they had done to get students to buy in:

> *I'm finding that gentle introduction seems to work well for them. I haven't had the pushback at all from them. I really felt like students embraced it fairly easily as long as it hasn't hit them very hard. They've been pretty responsive to it – I haven't had lower teacher evaluations. In fact, since doing this IBL process I've had higher teacher evaluations in my linear algebra course.*

Others mentioned that student buy-in had to be managed by maintaining morale, and as one interviewee said, the instructor's own commitment is important:

> *There needs to be a commitment to it that you're not gonna back off from it. Because I think when you back off, then the students will sense your lack of commitment and they will lose their trust, to some extent, in your credibility. Fortunately in my case, I was very assertive about certain things we were gonna do and we did and it worked out well, but I think it was important. Several times I said, "Look, you're just gonna have to trust me. This is gonna work."*

This comment also touches on another important aspect of getting buy-in, marketing (21 comments). Participants actively communicated the importance of IBL to their students to

explain the approach and generate their willingness to try it. On the first day of class, interviewees often did some sort of activity to explain what IBL was and why they were using it. For example, one speaker described analogies to other types of learning:

> *On the first day of class [I asked] the students to fill out an information card including what their hobbies were. Then when they would start to complain like , "Why won't you just lecture?," I could look up what their hobbies were and I could say, "Oh, you play video games, right? So would you get better at playing video games by watching me play video games or would you get better at playing video games by playing them yourself?"*

'Identity considerations' related to shifting roles in an IBL class. They include the second most common consideration, the changing role of the instructor in an IBL classroom (43 comments). Instructors talked about the shift from being the most vocal (or only) participant in a traditional lecture model to being much less vocal with IBL. Instructors described how they were not passive participants, however, but needed to thoughtfully craft class discussions to ensure that students were doing the intellectual work of the mathematics. As one interviewee characterized it:

> *The main role of the teacher is to be a facilitator, to facilitate the learning. The students should be the doer of the learning. They should be the ones actively doing, participating. I'm just facilitating the learning, but I shouldn't really be the one explicitly telling you what you need to be learning. Basically I'm like a guide…. [I] just set up the atmosphere.*

As instructors' roles shifted, students' roles also shifted. Interviewees only made 16 comments directly about students' roles in the classroom, and described successful IBL students as independent, engaged, active, and thinking critically. Additionally, descriptions of classroom practices in the previous section, Findings: Classroom Practices, also revealed dynamic, active student roles.

'Situational factors' included a few types of comments all related to the appropriate situations in which to use IBL, including class level (39 comments), class size (28 comments), student audience (22 comments), and physical space (7 comments). On most of these topics, there was not a general consensus. For class level, some interviewees mentioned that implementing IBL is often easier with upper-level courses where students are more skilled and the content lends itself more easily to proof-based, conceptual analyses. However, participants did also report using IBL in lower-level courses as well. Generally, IBL was thought to be easier with smaller class sizes, but larger classes could successfully use more group-work-based IBL. Interviewees also mentioned that sometimes IBL was not the best option for non-math majors, such as engineers, who needed to cover a broad range of computational procedures. Instructors felt that IBL was easier to accomplish in classrooms with tables and chairs that could easily be rearranged to promote interaction, instead of theater-style classrooms that draw attention to a lecturer at the front. These situational concerns were often related. For example, student audience, class size, and class level are all considerations for large, first-year, calculus courses filled with many science, technology, and engineering students as well as math majors. The interrelation of these factors and lack of consensus suggests that the decision to implement IBL is largely personal and dependent on the specific teacher and class.

Taken together, these 'considerations' show that novice IBL practitioners thoughtfully design and consider many aspects of their courses to help them run smoothly and successfully. In fact, interviewees made 23 comments specifically about the increased

amount of time required for planning IBL courses and for helping students, who more frequently came to office hours. Given all of these aspects of a course that must be carefully crafted, the week-long intensive workshops offered through this project seem to be a useful and necessary first step in making the transition to IBL. In the next section, we share interview participants' own thoughts on their development as IBL practitioners.

Development as IBL practitioners

In interviews, participants described how their beliefs about IBL shifted over time as they gained more understanding. Many of the interviewees had been exposed to IBL before attending the workshop, but did not always have the most favorable opinions. For example:

> *When I first heard about the Moore method I thought it was kind of cruel. The idea of …not allowing students to talk to anyone wasn't the way I felt…. [When I got to graduate school and they were using] a lot of group work, it made sense to me that these sort of deeper, more difficult problems would help students have a better grasp of mathematics because you're really struggling with it rather than doing just a bunch of rote problems…. It was when I was a young faculty member that I also started hearing about things like Modified Moore Method, where you would still not give the student any book to learn out of, but the students were able to work with each other. I always thought that that made more sense to me, because that was how I had learned. I knew I couldn't do it without any support. I sort of put that to the side…. Then I went to the workshop and I thought, "Oh, I don't have to do it by myself. There's support." That's where I said, "Oh, okay. I can do this."*

This broadened definition of IBL, including methods outside of the traditional Moore method, was quite common. In fact, 9 interviewees made 18 comments about viewing IBL as a spectrum of different practices. As this participant explained, that gave her the courage to try implementing IBL:

> *The conference kind of showed us that there's a whole spectrum to IBL and that it's okay to find what works for you and that doing something that doesn't work for you is not going to work, even if it works for someone else…. It was kind of a big moment for me because it made it seem less scary. The Moore Method is something that I don't feel comfortable applying. But feeling like I can pick and choose aspects of it, and find something on the spectrum that I feel comfortable with, was empowering.*

New practitioners found that IBL was nuanced and dynamic and required them to 'think on their feet.' Interviewees described how the transition from lecture to IBL was difficult, and that skill with IBL methods developed over time, involving many complementary changes. As this participant explained, successful, lively classroom discussions were a result of:

> *A lot of different things, a lot of small nuanced things – giving them problems which are at their level, not too hard and not too easy. Making the grading system a little bit more transparent. Having this computer program displaying what the priority list is on the board, so who is up next for giving a presentation, that sort of thing – a lot of different things.*

Additionally, instructors described how once they had started implementing IBL in one course, those techniques often spread into their other courses. For example,

> *Now I think that I'm getting students to go to the board more in those lecture-based classes. They're presenting homework problems at the beginning of class or maybe once a week, that sort of thing. We're having some discussion about it just like if it's an inquiry-based learning class.*

When reflecting back on their own development as IBL practitioners, participants were asked to give advice to those interested in using IBL. Many said the biggest hurdle was starting and that those interested should "go ahead and try it, at least some of it if not 100 percent." They also recommended getting support from mentors and colleagues at the beginning. Since the workshops gave participants a broadened view of IBL, the skills to begin implementing it, and access to experienced practitioners, according to these participants, the workshops may be an especially effective way to get new instructors to use IBL methods.

Conclusion

Overall, workshop participants were highly satisfied with the quality of the workshops. Though participants entered the workshops already holding strong beliefs in the effectiveness of inquiry-based learning, they reported significantly stronger beliefs after the workshops. Participants also reported significant increases in their knowledge about IBL and skill in implementing IBL.

Many participants reported implementing IBL practices in their own classroom during the year following the workshop, and many planned to use IBL techniques in future classes as well. Changes in reported teaching practices supported this and indicated a shift from instructor-centered lecture models to more active student participation including group work, presentations, and discussions.

Participant interviews supported self-reported implementation results and provided more detailed information about classroom practices. Participants identified some barriers to implementing IBL, but by thoughtfully designing their courses, most reported successfully using IBL methods in the year following the workshop they had attended. Participants spoke about how gaining understanding of the spectrum of IBL techniques made IBL more accessible, and how experienced practitioners from the workshops served as valuable mentors.

Additionally, survey findings, along with interview participants' reflections on their own development, reveal common themes that future workshops could use to help participants successfully adopt IBL techniques, including:

- Exposure to a broad 'spectrum' of IBL varieties, with discussions about the new roles for instructors and students
- Time and resources for developing IBL-appropriate course materials
- Specific strategies to deal with some of the major concerns of IBL implementers (i.e. student buy-in/resistance, marketing, coverage, techniques for participation, etc.)
- Ongoing support and inclusion in the broader community of IBL practitioners

Taken together, all evidence indicates that these workshops have helped participants make the transition from being observers interested in IBL to becoming IBL practitioners. The findings have also helped to reveal important factors for instructors beginning to make the change from instructor-centered methods to student-centered inquiry-based learning classrooms, and how workshop facilitators can support them in making the transition.

Acknowledgements

These workshops were supported by the National Science Foundation through collaborative grants to the host universities (DUE-0920173, DUE-0920057, DUE-0920786, and DUE-0920201). This evaluation was supported by the NSF under grant DUE-0920126. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

References Cited

Hayward, C., Kogan, M., & Laursen, S. (2012). *Collaborative research: Research, dissemination, and faculty development of Inquiry-Based Learning (IBL) methods in the teaching and learning of mathematics. Evaluation report: University of California, Santa Barbara (June 2012).* Report prepared for the NSF. Boulder, CO: University of Colorado Boulder: Ethnography & Evaluation Research.

IBM Corp. (2012). SPSS statistics, version 21. Armonk, NY: IBM Corp.

Kogan, M., & Laursen, S. (2011). *Collaborative research: Research, dissemination, and faculty development of Inquiry-Based Learning (IBL) methods in the teaching and learning of mathematics. Evaluation report: University of Michigan, Ann Arbor (May 2011).* Boulder, CO: University of Colorado Boulder: Ethnography & Evaluation Research.

Kogan, M., & Laursen, S. (2010). *Collaborative research: Research, dissemination, and faculty development of Inquiry-Based Learning (IBL) methods in the teaching and learning of mathematics. Evaluation report: University of Texas, Austin workshop (May 2010).* Boulder, CO: University of Colorado Boulder: Ethnography & Evaluation Research.

Laursen, S., Hunter, A.-B., Seymour, E., Thiry, H., & Melton, G. (2010). *Undergraduate research in the sciences: Engaging students in real science.* San Francisco, CA: Jossey-Bass.

Microsoft. (2011). Microsoft Excel for Mac. Redmond, WA.

National Science Foundation. (2008a). *TABLE 3. Employed doctoral scientists and engineers in 4-year educational institutions, by broad field of doctorate, sex, faculty rank, and years since doctorate: 2008*. Retrieved July 29, 2013, from Characteristics of Doctoral Scientists and Engineers in the United States: 2008: http://www.nsf.gov/statistics/nsf13302/pdf/tab3.pdf

National Science Foundation. (2008b). *TABLE 4. Employed doctoral scientists and engineers, by selected demographic characteristics and broad field of doctorate: 2008*. Retrieved July 29, 2013, from Characteristics of Doctoral Scientists and Engineers in the United States: 2008: http://www.nsf.gov/statistics/nsf13302/pdf/tab4.pdf

QSR International Pty Ltd. (2010). NVivo qualitative data analysis software, version 9.

Thiry, H., & Laursen, S. (2009). *Evaluation of the undergraduate research programs of Biological Sciences Initiative: Students' intellectual, personal, and professional outcomes from participation in research.* Boulder, CO: Ethnography & Evaluation Research.

Appendix A: Survey Instruments

Appendix A: Pre-workshop Survey

Welcome!

Dear workshop registrant,
Thank you for registering for the workshop on inquiry-based learning (IBL) at the University of California at Santa Barbara for summer 2012!

These workshops are offered to mathematics instructors under a grant from the National Science Foundation. As part of that grant-funded project, we'd like to gather some information from you about your experiences and perspectives on teaching college mathematics. Data will be used (1) to evaluate the workshop's effectiveness, (2) to improve future versions of the workshop, and (3) to provide general advice to others seeking to support faculty in improving teaching and learning in college mathematics.

This survey asks about your teaching experiences and preferences, your learning objectives for students, your expectations and personal reasons for registering for this workshop, and your prior knowledge of inquiry-based learning. Please mark the answer that best matches your response to each question.

Your participation is voluntary. You may skip questions you do not wish to answer, or choose not to participate. Your answers are anonymous and will not be reported in any way that may identify you individually; they will be aggregated with responses by other workshop participants. The workshop facilitators will not know how you answered, but we will provide a summary of responses to the facilitators to assist them in planning the workshop.

By completing this survey, in part or in whole, you agree that we may use this data to understand and improve faculty development for mathematics instruction. The data will also be used to provide a report to our funding agency on the effectiveness of the workshops. You may be invited to participate in follow-up surveys or interviews, but completing this survey now does not obligate you to participate in the future.

Thank you for your candid responses! We very much appreciate your assistance. And please contact us with any questions.

Sandra Laursen, study director
Marina Kogan, professional research assistant

Ethnography & Evaluation Research
University of Colorado at Boulder
www.colorado.edu/eer

sandra.laursen@colorado.edu
marina.kogan@colorado.edu

Your current career

Appendix A: Pre-workshop Survey

1. Your career stage:

- ◯ tenure-track faculty position, untenured
- ◯ tenure-track faculty position, tenured
- ◯ non-tenure-track faculty position
- ◯ high school teacher
- ◯ graduate student

Other (please specify)

2. Institution type:

- ◯ two-year college
- ◯ four-year college
- ◯ masters-granting comprehensive university
- ◯ Ph.D.-granting research university

Other (please specify)

3. Is your institution designated as a minority-serving institution?

- ◯ yes
- ◯ no
- ◯ don't know

Your teaching background

4. Your teaching experience as a college instructor. (Do not include graduate school teaching or TA experience unless you are currently a graduate student.)

- ◯ <2 years
- ◯ 2-5 years
- ◯ 6-10 years
- ◯ 11-20 years
- ◯ >20 years

5. Have you ever TAKEN a class that used inquiry-based learning (IBL) or the Moore Method? Please explain.

Appendix A: Pre-workshop Survey

6. Have you ever TAUGHT a class using inquiry-based learning (IBL) or the Moore Method? Please explain.

7. What do you hope to gain by participating in this workshop?

Your teaching goals

When you answer the next two questions, please have a specific course in mind for which you would consider using IBL methods.

8. Please tell us the name of the course you have in mind

9. Who would be the student audience for this course?

- ◯ mostly math majors
- ◯ mixed STEM majors (science, technology, engineering, mathematics)
- ◯ non-STEM majors
- ◯ pre-service teachers
- ◯ other

Other (please specify)

10. Who would be a typical student in this course:

◯ first-year ◯ sophomore ◯ junior or senior ◯ mixed class levels

Your teaching goals

Please keep the same course in mind for this question.

Appendix A: Pre-workshop Survey

11. Consider your goals for students in this course. How important is each of the following?

	not very important	somewhat important	quite important	the most important
learning specific mathematical ideas	◯	◯	◯	◯
understanding mathematical concepts deeply	◯	◯	◯	◯
applying mathematics to other fields	◯	◯	◯	◯
applying mathematics to everyday life	◯	◯	◯	◯
understanding the nature of mathematics	◯	◯	◯	◯
understanding the role of proof in mathematics	◯	◯	◯	◯
thinking critically	◯	◯	◯	◯
developing skills in problem-solving	◯	◯	◯	◯
becoming more independent in problem-solving	◯	◯	◯	◯
gaining confidence in doing mathematics	◯	◯	◯	◯
communicating mathematics orally	◯	◯	◯	◯
communicating mathematics in writing	◯	◯	◯	◯
appreciating the beauty or significance of mathematical ideas	◯	◯	◯	◯

Other (please specify)

Your teaching practices

Please keep the same course in mind for this question.

Appendix A: Pre-workshop Survey

12. Last time you taught this course, on average, how often did you use the following teaching methods during class? Please mark the answer that best matches your teaching practices.

	Never	About once a month	About twice a month	Weekly	Every class
Instructor lecture	◯	◯	◯	◯	◯
Instructor solving problems or examples on the board	◯	◯	◯	◯	◯
Instructor asking conceptual questions to lead to generalization	◯	◯	◯	◯	◯
Instructor-led whole class discussions	◯	◯	◯	◯	◯
Student-led whole group discussions	◯	◯	◯	◯	◯
Student small group discussions	◯	◯	◯	◯	◯
Student collaborative work in small groups	◯	◯	◯	◯	◯
Student individual problem-solving (in class)	◯	◯	◯	◯	◯
Student individual writing (in class)	◯	◯	◯	◯	◯
Student-led presentation of problems or proofs	◯	◯	◯	◯	◯
Computer-assisted learning	◯	◯	◯	◯	◯

Your perspectives on inquiry

13. How would you rate your current level of KNOWLEDGE of inquiry-based learning in mathematics education?

◯ None ◯ A little ◯ Some ◯ A lot

14. How would you rank your current level of SKILL in inquiry-based teaching?

◯ None ◯ A little ◯ Some ◯ A lot

15. To what extent do you believe inquiry-based strategies are an EFFECTIVE learning method?

◯ Don't know ◯ Not very effective ◯ Somewhat effective ◯ Highly effective

16. How MOTIVATED do you feel to incorporate inquiry into your teaching methods?

◯ Not at all ◯ A little bit ◯ Somewhat motivated ◯ Highly motivated

17. How do you define inquiry-based learning at this time?

Your expectations about IBL

Appendix A: Pre-workshop Survey

18. What do you expect your students to gain from inquiry-based learning?

19. What do you expect to gain personally from employing IBL teaching methods?

20. What concerns you about using IBL methods in the classroom?

Your expectations about IBL

21. Consider the following possible student outcomes from a college mathematics course. How would you expect these outcomes to be affected by the use of IBL methods?

	negative effect	little or no effect	some positive effect	strong positive effect
learning specific mathematical ideas	◯	◯	◯	◯
understanding mathematical concepts deeply	◯	◯	◯	◯
applying mathematics to other fields	◯	◯	◯	◯
applying mathematics to everyday life	◯	◯	◯	◯
understanding the nature of mathematics	◯	◯	◯	◯
understanding the role of proof in mathematics	◯	◯	◯	◯
thinking critically	◯	◯	◯	◯
developing skills in problem-solving	◯	◯	◯	◯
becoming more independent in problem-solving	◯	◯	◯	◯
gaining confidence in doing mathematics	◯	◯	◯	◯
communicating mathematics orally	◯	◯	◯	◯
communicating mathematics in writing	◯	◯	◯	◯
appreciating the beauty or significance of mathematical ideas	◯	◯	◯	◯

Demographic information

These workshops are funded by the National Science Foundation, a federal agency that requires that data about participants be collected in a form that can be analyzed for differences by gender and ethnicity.

22. Your gender

◯ Male

◯ Female

Appendix A: Pre-workshop Survey

23. Your race or ethnicity

- ◯ African or African descent
- ◯ Asian or Asian descent
- ◯ European or European descent
- ◯ Latino (of any race)
- ◯ Middle Eastern or Middle Eastern descent
- ◯ Native American or Native Alaskan
- ◯ Pacific Islander
- ◯ Multiracial

Other (please specify)

Survey matching code

We will be conducting follow-up surveys of workshop participants. In order to match pre- and post-survey data, we need a stable and unique identifier for each respondent. This information will not be used for any other purpose.

24. Please enter your birthdate:

	MM	DD	YYYY
birthdate		/ /	

25. What model car do you drive?

Thank you!

Thank you for completing the survey, and for your interest in the workshop. Please contact the workshop organizers with any questions about the workshop:

Bill Jacob
jacob@math.ucsb.edu

Please contact the evaluation team with any questions about this survey:

Sandra Laursen, sandra.laursen@colorado.edu
Marina Kogan, marina.kogan@colorado.edu

Appendix A: Post-Workshop Survey

Welcome!

Dear workshop participant,
Congratulations on completing the workshop on inquiry-based learning (IBL) at the University of California at Santa Barbara.

These workshops are offered to mathematics instructors under a grant from the National Science Foundation. As part of that grant-funded project, we'd like to gather some information from you about your experiences at the workshop and your perspectives on teaching college mathematics. Data will be used (1) to evaluate the workshop's effectiveness, (2) to improve future versions of the workshop, and (3) to provide general advice to others seeking to support faculty in improving teaching and learning in college mathematics.

This survey asks about your teaching experiences and preferences, your learning objectives for students, and your impressions of the IBL workshop you attended. Please mark the answer that best matches your response to each question.

Your participation is voluntary. You may skip questions you do not wish to answer, or choose not to participate. Your answers are anonymous and will not be reported in any way that may identify you individually; they will be aggregated with responses by other workshop participants. The workshop facilitators will not know how you answered, but we will provide a summary of responses to the facilitators to assist them in improving future workshops.

By completing this survey, in part or in whole, you agree that we may use this data to understand and improve faculty development for mathematics instruction. The data will also be used to provide a report to our funding agency on the effectiveness of the workshops. You may be invited to participate in follow-up surveys or interviews, but completing this survey now does not obligate you to participate in the future.

Thank you for your candid responses! We very much appreciate your assistance. And please contact us with any questions.

Sandra Laursen, study director
Marina Kogan, professional research assistant

Ethnography & Evaluation Research
University of Colorado at Boulder
www.colorado.edu/eer

sandra.laursen@colorado.edu
marina.kogan@colorado.edu

Your workshop experience

1. Compared to other professional development workshops that you have attended, please rate the OVERALL quality of this workshop.

◯ Poor ◯ Below average ◯ Fair or average ◯ Good ◯ Excellent

2. Please rate the LOGISTICS (food, facilities, timing, length, breaks, etc.).

◯ Poor ◯ Below average ◯ Fair or average ◯ Good ◯ Excellent

Appendix A: Post-Workshop Survey

3. Please explain your rating.

Your workshop experience

Please focus now on your learning experience in the workshop, separately from the logistics issues already discussed.

4. What one or two things were BEST about the workshop?

5. What one or two aspects of the workshop most need to be IMPROVED?

6. Please comment on any other aspects of your workshop experience.

Appendix A: Post-Workshop Survey

Your learning from the workshop

7. Using complete sentences, please summarize the main message you will take away from this workshop.

8. How would you rate your current level of KNOWLEDGE of inquiry-based learning in mathematics education?

- ◯ None
- ◯ A little
- ◯ Some
- ◯ A lot

9. How would you rank your current level of SKILL in inquiry-based teaching?

- ◯ None
- ◯ A little
- ◯ Some
- ◯ A lot

Your learning from the workshop

10. To what extent do you believe inquiry-based strategies are an EFFECTIVE learning method?

- ◯ Don't know
- ◯ Not very effective
- ◯ Somewhat effective
- ◯ Highly effective

11. How MOTIVATED do you feel to incorporate inquiry into your teaching methods?

- ◯ Not at all
- ◯ A little bit
- ◯ Somewhat motivated
- ◯ Highly motivated

12. How do you define inquiry-based learning at this time?

Your learning from the workshop

Appendix A: Post-Workshop Survey

13. What do you expect your STUDENTS to gain from inquiry-based learning?

14. What do you expect to gain PERSONALLY from employing IBL teaching methods?

15. What concerns you about using IBL methods in the classroom?

Your plans for IBL teaching

Your answers to the following questions will help us to follow up with you at an appropriate time after the workshop.

16. How likely is it that you will implement IBL methods in a mathematics course:

	Not at all likely	Somewhat unlikely	Somewhat likely	Rather likely	Definitely
in the coming academic year?	◯	◯	◯	◯	◯
if not this year, in a future year?	◯	◯	◯	◯	◯

Appendix A: Post-Workshop Survey

17. Besides teaching a class using IBL methods, are there any OTHER ways in which you expect your future teaching will be informed by this workshop? Please explain.

Your plans for IBL teaching

Please select one course where you are MOST likely to implement IBL, and reply to the following questions with that specific course in mind.

18. Student audience:

- ◯ mostly math majors
- ◯ mixed STEM majors (science, technology, engineering, mathematics)
- ◯ non-STEM majors
- ◯ pre-service teachers
- ◯ other

Other (please specify)

19. Typical class size:

- ◯ under 20
- ◯ 20-35
- ◯ 35-50
- ◯ over 50

Your plans for IBL teaching

Please reply keeping in mind the same specific course where you are MOST likely to implement IBL (continued):

20. Typical student:

- ◯ first-year
- ◯ sophomore
- ◯ junior or senior
- ◯ mixed class levels

21. Expected timing (approximate starting month and year of the academic term in which this course would start - e.g., 09/15/2011, 01/20/2012, etc.).

	MM	DD	YYYY
Semester:	/	/	

Appendix A: Post-Workshop Survey

22. Please describe your current plans for this course in a few words:

Your plans for IBL teaching

23. What kinds of support would help you most as you plan or implement IBL methods in the coming year? Please explain.

24. The workshop facilitators would like to offer help in the way that would be most likely to actually be useful to you. Please indicate the form of help that you would be most likely to draw upon.

	not likely to participate	somewhat likely to participate	very likely to participate
Email listserv for exchanging ideas and getting advice from other workshop participants & facilitators	◯	◯	◯
Email list for receiving articles, web links, and other resources from facilitators	◯	◯	◯
Web-based discussion board or chat room	◯	◯	◯
Occasional personal phone call or e-mail from facilitators	◯	◯	◯

Other (please explain)

Survey matching code

We will be conducting follow-up surveys of workshop participants. In order to match pre- and post-survey data, we need a stable and unique identifier for each respondent. This information will not be used for any other purpose.

Appendix A: Post-Workshop Survey

25. Please enter your birthdate:

MM DD YYYY

birthdate ____ / ____ / ____

26. What model car do you drive?

Thank you!

Thank you for completing the survey, and for your contributions to making this workshop a success!

Please contact the workshop organizers with any questions about the workshop or your course planning:

Bill Jacob
jacob@math.ucsb.edu

Please contact the evaluation team with any questions about this survey:

Sandra Laursen, sandra.laursen@colorado.edu
Marina Kogan, marina.kogan@colorado.edu

Appendix A: Follow-Up Survey

Welcome!

Dear workshop graduate,

In June 2012, you participated in a workshop on inquiry-based learning (IBL) in mathematics at the University of California - Santa Barbara. At the workshop, we asked for your immediate impressions of the workshop and what you learned. Now we would like to know whether you have implemented IBL in any of your own courses and hear about your experiences with it. If you did not implement IBL methods in your courses, we would still like to hear from you, as it is important to document the challenges that faculty face in applying new teaching methods.

We are asking you to reflect on the courses you completed this past academic year (2012-2013), not the courses you may currently be teaching. This survey asks about your learning objectives for students, your teaching practices, and your knowledge of inquiry-based learning.

If you implemented IBL approaches in any of your courses since the workshop, we will also ask about your experiences in doing that. If you did not implement IBL techniques, we would like to know more about why you did not. Please mark the answer that best matches your response to each question.

Your participation is voluntary. You may skip questions you do not wish to answer, or choose not to participate. Your answers are anonymous and will not be reported in any way that may identify you individually; they will be aggregated with responses by other workshop participants.

By completing this survey, in part or in whole, you agree that we may use this data to understand and improve faculty development for mathematics instruction. The data will also be used to provide a report to our funding agency on the effectiveness of the workshops. You may be invited to participate in a follow-up interview, but completing this survey now does not obligate you to participate in the future.

Thank you for your candid responses! We very much appreciate your assistance. And please contact us with any questions.

Chuck Hayward, professional research assistant
Sandra Laursen, study director

Ethnography & Evaluation Research
University of Colorado at Boulder
www.colorado.edu/eer

sandra.laursen@colorado.edu
chuck.hayward@colorado.edu

Your current career

First we'd like to know a bit about your professional situation.

Appendix A: Follow-Up Survey

1. Your career stage:

- ◯ tenure-track faculty position, untenured
- ◯ tenure-track faculty position, tenured
- ◯ non-tenure-track faculty position
- ◯ high school teacher
- ◯ graduate student

Other (please specify)

2. Institution type:

- ◯ two-year college
- ◯ four-year college
- ◯ masters-granting comprehensive university
- ◯ Ph.D.-granting research university

Other (please specify)

3. Have you changed positions since you attended the IBL workshop at UC - Santa Barbara in June 2012?

- ◯ Yes
- ◯ No

If yes, please explain

Your teaching background

4. Your teaching experience as a college instructor. (Do not include graduate school teaching or TA experience unless you are currently a graduate student.)

- ◯ <2 years
- ◯ 2-5 years
- ◯ 6-10 years
- ◯ 11-20 years
- ◯ >20 years

Appendix A: Follow-Up Survey

5. During the workshop, afternoon sessions were split into a calculus-track group and pre-service teaching group. Which sessions did you attend MORE often?

- ◯ I attended the Calculus-track group more often
- ◯ I attended the pre-service teaching group more often
- ◯ I attended them equally

6. Have you implemented an IBL course since the workshop in June 2012?

- ◯ No
- ◯ Not a fully IBL course, but have applied some IBL approaches
- ◯ Yes, one course
- ◯ Yes, more than one course

IBL Implementation

7. How many total courses have you used IBL methods in (either partially or fully) since the workshop in June 2012?

- ◯ 1
- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 5 or more

8. How many total students have you taught using IBL methods since the workshop (please estimate)?

IBL course implemented

9. For the next few questions, please select ONE course that you taught using IBL methods. If you implemented IBL in more than one course, please pick the more IBL-intensive course. What is the name of this course?

Appendix A: Follow-Up Survey

10. During which semester/quarter did you implement this course?

- [ ] Fall
- [ ] Winter
- [ ] Spring

11. Who was the student audience in this IBL class you taught?

- ◯ mostly math majors
- ◯ mixed STEM majors (science, technology, engineering, mathematics)
- ◯ non-STEM majors
- ◯ pre-service teachers
- ◯ other

Other (please specify)

12. Class size:

- ◯ under 20
- ◯ 20-35
- ◯ 35-50
- ◯ over 50

13. Typical student:

- ◯ first-year
- ◯ sophomore
- ◯ junior or senior
- ◯ mixed class levels

Your teaching goals

Please continue to answer in regards to the ONE specific IBL course.

Appendix A: Follow-Up Survey

14. Consider your goals for students in your IBL course. How important were each of the following?

	not very important	somewhat important	quite important	the most important
learning specific mathematical ideas	◯	◯	◯	◯
understanding mathematical concepts deeply	◯	◯	◯	◯
applying mathematics to other fields	◯	◯	◯	◯
applying mathematics to everyday life	◯	◯	◯	◯
understanding the nature of mathematics	◯	◯	◯	◯
understanding the role of proof in mathematics	◯	◯	◯	◯
thinking critically	◯	◯	◯	◯
developing skills in problem-solving	◯	◯	◯	◯
becoming more independent in problem-solving	◯	◯	◯	◯
gaining confidence in doing mathematics	◯	◯	◯	◯
communicating mathematics orally	◯	◯	◯	◯
communicating mathematics in writing	◯	◯	◯	◯
appreciating the beauty or significance of mathematical ideas	◯	◯	◯	◯

Other (please specify)

Your teaching practices

Please continue to answer in regards to the ONE specific IBL course.

Appendix A: Follow-Up Survey

15. When you taught this course (*[Q9]*), on average, how often did you use the following teaching methods during class? Please mark the answer that best matches your teaching practices.

	Never	About once a month	About twice a month	Weekly	Every class
Instructor lecture	◯	◯	◯	◯	◯
Instructor solving problems or examples on the board	◯	◯	◯	◯	◯
Instructor asking conceptual questions to lead to generalization	◯	◯	◯	◯	◯
Instructor-led whole class discussions	◯	◯	◯	◯	◯
Student-led whole group discussions	◯	◯	◯	◯	◯
Student small group discussions	◯	◯	◯	◯	◯
Student collaborative work in small groups	◯	◯	◯	◯	◯
Student individual problem-solving (in class)	◯	◯	◯	◯	◯
Student individual writing (in class)	◯	◯	◯	◯	◯
Student-led presentation of problems or proofs	◯	◯	◯	◯	◯
Computer-assisted learning	◯	◯	◯	◯	◯

Student outcomes of IBL

16. How were the following student outcomes affected by the use of IBL methods?

	negative effect	little or no effect	some positive effect	strong positive effect
learning specific mathematical ideas	◯	◯	◯	◯
understanding mathematical concepts deeply	◯	◯	◯	◯
applying mathematics to other fields	◯	◯	◯	◯
applying mathematics to everyday life	◯	◯	◯	◯
understanding the nature of mathematics	◯	◯	◯	◯
understanding the role of proof in mathematics	◯	◯	◯	◯
thinking critically	◯	◯	◯	◯
developing skills in problem-solving	◯	◯	◯	◯
becoming more independent in problem-solving	◯	◯	◯	◯
gaining confidence in doing mathematics	◯	◯	◯	◯
communicating mathematics orally	◯	◯	◯	◯
communicating mathematics in writing	◯	◯	◯	◯
appreciating the beauty or significance of mathematical ideas	◯	◯	◯	◯

Appendix A: Follow-Up Survey

17. Overall, what do you see as the greatest benefits to your students of inquiry-based learning?

18. What concerns you most about what students may NOT gain from inquiry-based learning?

Instructor outcomes of IBL

19. What did you gain personally from employing IBL teaching methods?

20. What problems have you encountered with using IBL methods in the classroom?

Resources you used

21. Looking back, what aspect of the workshop in June 2012 was most useful for your IBL implementation?

22. Consider different resources that the organizers of the workshop made available to you. Please rate them on how helpful they were for your IBL implementation.

	No help	A little help	Moderate help	Much help	Great help	Not applicable
Email listserv for exchanging ideas and getting advice from other workshop participants & facilitators	◯	◯	◯	◯	◯	◯
Email list for receiving articles, web links, and other resources from facilitators	◯	◯	◯	◯	◯	◯
Occasional personal phone call or e-mail from facilitators	◯	◯	◯	◯	◯	◯

Appendix A: Follow-Up Survey

23. Do you keep in touch with any other workshop participants?

- ◯ Yes, fairly often
- ◯ Yes, once in a while
- ◯ No

Resources, continued

24. Please share any other resources that were helpful to you in implementing your IBL course - workshops, conferences, books, and so on.

25. What other resources would be useful to support your IBL teaching?

Challenges to implementing IBL

26. If you did not implement IBL in any courses this year, please tell us why.

27. Do you expect to implement IBL in a course in the future?

- ◯ yes, definitely
- ◯ maybe
- ◯ no

Your perspectives on inquiry

28. How would you rate your current level of KNOWLEDGE of inquiry-based learning in mathematics education?

◯ None ◯ A little ◯ Some ◯ A lot

Appendix A: Follow-Up Survey

29. How would you rank your current level of SKILL in inquiry-based teaching?

○ None ○ A little ○ Some ○ A lot

30. To what extent do you believe inquiry-based strategies are an EFFECTIVE learning method?

○ Don't know ○ Not very effective ○ Somewhat effective ○ Highly effective

31. How MOTIVATED do you feel to incorporate inquiry into your teaching methods?

○ Not at all ○ A little bit ○ Somewhat motivated ○ Highly motivated

32. How do you define inquiry-based learning at this time?

Institutional Context

33. Please tell about the support at your institution for IBL teaching from the following colleagues:

	not at all supportive	mostly not supportive	mixed or moderate support	mostly supportive
Your colleagues in the department	○	○	○	○
Your department head or chair	○	○	○	○
Your dean or provost	○	○	○	○
Your colleagues outside the department	○	○	○	○

34. Please describe ways in which your department or institution has or has not supported your IBL teaching interests.

Appendix A: Follow-Up Survey

35. Have you shared any of your IBL-related knowledge from the workshop with other colleagues?

- ◯ Yes, with colleagues in my own department
- ◯ Yes, with math colleagues outside my own department
- ◯ Not yet, but I plan to
- ◯ No

Please explain

IBL Events

36. Have you participated in any IBL-related events since the workshop? Please check all that apply.

	Attended	*Presented*
No IBL-related events	☐	☐
Legacy of R.L.Moore Conference, Austin TX, June 2013	☐	☐
IBL-related sessions at JMM, San Diego CA, January 2013	☐	☐
IBL-related session at MAA Section Meeting	☐	☐
"IBL Best Practices" at MathFest, Madison WI, August 2012	☐	☐
"IBL Best Practices" at MathFest, Hartford CT, August 2013	☐	☐
Other IBL Workshops or meetings (please specify)	☐	☐

Please explain your "other" answer.

Appendix A: Follow-Up Survey

37. Have you used any forms of IBL support since the workshop? Please check all that apply.

- [ ] None
- [ ] Applied for AIBL mini-grant
- [ ] Received AIBL mini-grant
- [ ] Participated in AIBL mentor program
- [ ] AIBL Visiting Speaker's Bureau
- [ ] Read post-workshop e-mail listserv
- [ ] Contributed to post-workshop e-mail listserv
- [ ] Other

Please explain your "other" answer.

Demographic information

These workshops are funded by the National Science Foundation, a federal agency that requires that data about participants be collected in a form that can be analyzed for differences by gender and ethnicity.

38. Your gender

- ◯ Male
- ◯ Female

39. Your race or ethnicity

- ◯ African or African descent
- ◯ Asian or Asian descent
- ◯ European or European descent
- ◯ Latino (of any race)
- ◯ Middle Eastern or Middle Eastern descent
- ◯ Native American or Native Alaskan
- ◯ Pacific Islander
- ◯ Multiracial

Other (please specify)

Survey matching code

Appendix A: Follow-Up Survey

In order to match your responses with earlier pre- and post-survey data, we need a stable and unique identifier for each respondent. This information will not be used for any other purpose.

***40. Please enter your birthdate:**

MM DD YYYY

birthdate ____ / ____ / ____

41. What model car do you drive? (If it has changed since the workshop in June 2012, please answer with the car you drove at that time.)

Thank you!

Thank you for completing the survey.

Please contact the evaluation team with any questions about this survey:

Sandra Laursen, sandra.laursen@colorado.edu
Chuck Hayward, chuck.hayward@colorado.edu

Appendix B: Interview Protocol

Evaluation of Dissemination and Faculty Development of
Inquiry-Based Learning (IBL) Methods in the Teaching and Learning of Mathematics

Individual Interview Protocol for IBL Implementers

10/24/12

- Review consent form, confidentiality and anonymity. Audio recording procedures.
- Turn on mic!

This interview is to find out more about your experiences both at the workshop and in your classroom. I will start by just asking you some background information about your teaching experience. Then, we will briefly discuss the workshop. On your survey, it sounds like you've used some IBL methods, so we'll explore that more in-depth for the bulk of the interview.

(**Bold** questions should be asked in every interview. Other questions can be asked as necessary.)

Background and experience

Tell me a bit about yourself:

- ☐ **Where do you teach?**
- ☐ **How long have you been at your institution? What is your position (grad student? Post doc?** Associate or full professor?)
- ☐ **What mathematics courses have you taught?**
- ☐ Have you co-taught mathematics?
    - As relevant: Worked closely with TAs?
- ☐ **How long have you been interested in inquiry-based learning? How did you learn about IBL in undergraduate mathematics?**
- ☐ Are there (any other) faculty in your department involved in inquiry-based learning?
- ☐ **What motivated you to participate in the workshop?**

Review of workshop participation

- ☐ Do you remember how you found out about the IBL workshop?
- ☐ Prior to the workshop, what did you know about IBL in mathematics?
- ☐ **Why led you to sign up for the workshop?**
- ☐ **I know it was a long time ago, but what has stuck with you from the workshop?**
- ☐ What did you think about how the IBL workshop went overall? Informative? Not informative?
- ☐ What do you think were the most useful things you got out of it?

- ☐ What didn't work, in your view?
- ☐ **Have you participated in any other IBL workshops since? Have you visited other classrooms to observe IBL teaching? Any other ways that you've continued to educate yourself about IBL? (reading, conversations)**

Experience with and views of IBL teaching and learning and post-workshop implementation of IBL in their classrooms

- ☐ Other than the workshop did you have any previous training in using IBL instructional methods?
- ☐ **What is/give me your definition of IBL teaching?**
- ☐ **Describe for me how you typically taught your classes before implementing IBL methods:**

Listen/probe for:

- Lecturing
- Single student presentation
- Group presentation
- Small group problem-solving
- Small group discussions
- Whole class discussion
- Individual homework assignments
- Group homework assignments
- In class exams
- Take-home exams

- ☐ **Have you had an opportunity to implement any IBL methods in any of your classes?**
- ☐ **In which classes did you implement IBL methods? Some? All? Which ones? How did you decide where it seemed appropriate?**

Listen/probe for:

- Introductory/lower level
- Advanced/ major courses

- ☐ **Take me through day one of IBL. What did you do? (use this to see if there was any messaging/ 'selling it' to students)**
- ☐ **Describe for me how – if at all - your teaching has changed using IBL methods (past day one)?**

Listen/probe for:

- Lecturing
- Singe student presentation
- Group presentation
- Small group problem-solving
- Small group discussions
- Whole class discussion
- Individual homework assignments
- Group homework assignments
- In class exams
- Take-home exams

☐ **How did students respond?**

☐ **What worked? What didn't work?**

☐ What would you do differently?

☐ **What are the benefits you see in using IBL methods?**

☐ **What are the challenges in using IBL methods?**

☐ **Did you notice differences in students' learning outcomes? Different groups?**

☐ ***Describe the trajectory of your opinions on IBL from when you first heard of it, through the workshop, and in the year since.***

☐ ***Have you had any specific experiences or observations that have led you to increase or decrease your use of IBL methods? (idea of refreezing with faculty development)***

☐ ***What ideas do you have to further refine your use of IBL? What will you try next?***

☐ **Do you plan to continue to use IBL in your teaching? All courses? Some courses? Why? Why not?**

☐ **Other than in the classroom, how does IBL affect your work as a teaching with planning, office hours, grading, etc.?**

Listen/probe for:

- More time for grading
- More office hours? And different uses of office hour time.
- Different nature of preparing for class

☐ ***Have you developed any new structures or activities as you've gained experience with IBL methods? (use as vehicle to uncover the main themes important in teaching IBL)***

☐ ***What has your biggest struggle been with using IBL?***

Views of teaching and learning mathematics

- ☐ What skills and knowledge do you think are needed for successful teaching of undergraduate mathematics?
- ☐ What kind of instructional activities do you consider work best?
- ☐ What is the role of a teacher in a mathematics classroom?
- ☐ What is the role of students in a mathematics classroom?
- ☐ What kinds of students learn best college mathematics?
- ☐ What students need to do in order to succeed in college mathematics?
- ☐ What are your strengths and weaknesses as a mathematics teacher?

Degree of Department Support

- ☐ How would you characterize your department's general view of IBL teaching? Particular faculty? Your Chair? Are they supportive? Not supportive? Neutral?
- ☐ **What situational or departmental factors have encouraged or helped you in teaching with IBL?**
- ☐ **What situational or departmental factors have discouraged or helped you in teaching with IBL?**

Advice

- ☐ **Any advice you'd want to give others interested in teaching mathematics using IBL methods?**
- ☐ **Any advice you'd want to give the workshop leaders?**
- ☐ **Anything we should have asked that we didn't? Anything you want to add or emphasize?**

Thanks, follow-up, goodbye.