Supporting Mathematics Instructors' Adoption of Inquiry-Based Learning (IBL): Lessons from Professional Development Workshops

Charles N. Hayward
Ethnography & Evaluation Research, University of Colorado Boulder

Mathematics serves as a gateway course for achieving any college degree (Stigler, Givvin, & Thompson, 2010), especially for students in STEM fields (Seymour & Hewitt, 1997). Studies have shown that when instructors use student-centered teaching methods, students are more likely to persist in STEM majors (Ellis, Kelton, & Rasmussen, 2014; Freeman, et al., 2014). Inquiry-based learning (IBL) is a student-centered form of college mathematics instruction in which instructors guide students through ill-defined problems and engage students in discussing and critiquing mathematical arguments (Prince & Felder, 2007; Savin-Baden & Major, 2004). IBL classes help students to develop positive attitudes, beliefs, and capacities that support learning and problem-solving in mathematics (Hassi & Laursen, in press). In IBL classes, female students benefit from affective gains and improved persistence with math majors, and low-performing students benefit from improved grades (Kogan & Laursen, 2014; Laursen, Hassi, Kogan, & Weston, 2014).

Despite these benefits, IBL shares a challenge with other instructional reforms – getting large numbers of faculty to use them (Fairweather, 2008; Henderson & Dancy, 2007; 2008; 2011). Professional development workshops are one strategy for supporting instructors in adopting student-centered teaching methods. They are the preferred method of National Science Foundation (NSF) program directors (Khatri, Henderson, Cole, & Froyd, 2013), and there is some evidence to support this belief. In one study with

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engineering faculty, among six different types of professional development, workshop participation had the strongest correlation with instructors' use of student-centered pedagogies (Lattuca, Bergom, & Knight, 2014).

We report here on findings on instructional changes made by instructors after participating in a week-long, intensive faculty workshop that show how these workshops effectively helped attendees to adopt IBL techniques in their own classrooms. While we report more extensive findings elsewhere (Hayward, Kogan, & Laursen, 2014; Hayward & Laursen, 2014), given the focus of this conference on transforming institutions, here we share those findings related to broadening the adoption of IBL and similar, student-centered strategies in college mathematics and in other disciplines.

The Workshops and Participants

Data were collected from each of three annual workshops held between 2010 and 2012 and from pre-surveys, post-surveys, and one-year follow-up surveys, as well as some interviews. Each of the workshops was four or five days long and served between 40 and 55 participants. The workshops were part of a larger project, but each was independently organized. As a result, they shared common elements but each engaged participants in its own mix of activities such as watching and analyzing videos of IBL classrooms, listening to plenary talks, participating in panel discussions with experienced IBL instructors, and reading and discussing IBL-related articles. The first and third workshops featured work sessions for participants to collaborate and develop IBL materials, whereas the second workshop was larger and organized in more of a conference style with formal talks. All three workshops exemplified characteristics of effective research-based professional development that have been identified in previous literature (Cormas & Barufaldi, 2011). Together, they served 139 participants. From these participants, we received 124 pre-workshop surveys (89%), 125 post-workshop surveys (90%), and 96 follow-up surveys (69%). Using anonymous identifiers, we were able to match each individual's surveys from the three time points. We successfully matched 100 (80%) post-surveys and 69 (72%) follow-up surveys. The high response rates indicate that the responses can be generalized to the workshop population, and are not strongly biased by subgroups such as adopters versus non-adopters. In addition, we conducted sixteen interviews to gain a deeper understanding of participants' views on teaching and learning, and their development as instructors. We use these interviews in the discussion to help explain findings from the surveys.

Overall, 56% of workshop participants were men and 40% were women. Most reported being of European descent (69%), and some were of Asian (10%) or African (5%) descent. Participants varied in career status, with about one-third each being untenured faculty (35%), tenured faculty (34%), and non-tenure-track faculty (27%). Almost half of participants (47%) were newer faculty with five years or less of teaching experience, and the rest ranged from six to over 20 years of experience. Participants worked at Ph.D.-granting institutions (36%), four-year colleges (36%), master's-granting comprehensive universities (23%), and two-year colleges (4%). In total, 13% of participants reported working at a minority-serving institution. While some participants had experienced IBL as a student (24%) or previously incorporated IBL methods into their teaching (45%), about half (46%) had no experience with IBL as either a teacher or a student. The demographics of the sixteen interview participants were roughly equivalent to those of the larger group, though there were more women (56%) than men (44%).

In our role as evaluators for these workshops, we collected data to help evaluate the workshop, such as participants' ratings of the workshop's quality and logistics, as well as more general items about participants' beliefs about teaching and learning, and their goals for their students' learning. We also asked participants to rate their skill with and knowledge of IBL methods, as well as their beliefs in its effectiveness and motivation to use it. Comparisons of participants' responses to these four items over time revealed that the workshops were high in quality and led to sustained improvements in participants' knowledge, skills, and attitudes toward IBL. Full results of this analysis and other analyses are available in the evaluation report (Hayward & Laursen, 2014) and an upcoming paper (Hayward, Kogan, & Laursen, 2014). In this report, we focus on measures of participants' implementation of IBL and on how the framing of the workshops contributed to participants' receptivity to and implementation of the teaching approaches the workshops espoused.

Results

In the year following the workshop, 58% of participants reported implementing at least some IBL methods in their classroom. This included 29% who reported using "some IBL methods," 14% who reported teaching "one full-IBL course," and 15% who reported teaching "more than one full-IBL course." Only 8% reported using "no IBL methods," while the remaining 34% did not respond to this question.

As a check on participants' self-described "IBL" teaching, we also measured implementation indirectly. Participants reported the frequency with which they used certain teaching practices on both pre-workshop surveys and one-year follow-up surveys. By comparing matched surveys, we were able to assess changes in teaching practices that were consistent with the inquiry-based practices presented in the workshops, as well as some non-inquiry-based practices that could be considered controls. In Figure 1, participants' reports of their use of eleven specific pre-workshop teaching practices are compared to their reports of these same teaching practices at the one-year follow-up for the 69 respondents with matched surveys. Asterisks indicate significant changes in these frequencies. Upward arrows indicate increased frequency of the practice and downward arrows indicate decreased frequency. We tested for differences in the change in individuals' teaching practices using Wilcoxon Signed Ranks tests, which revealed the significant changes detailed in Table 1. The use of other practices did not differ significantly from pre-workshop to one-year follow-up; they are shown in Figure 1 but not in Table 1.

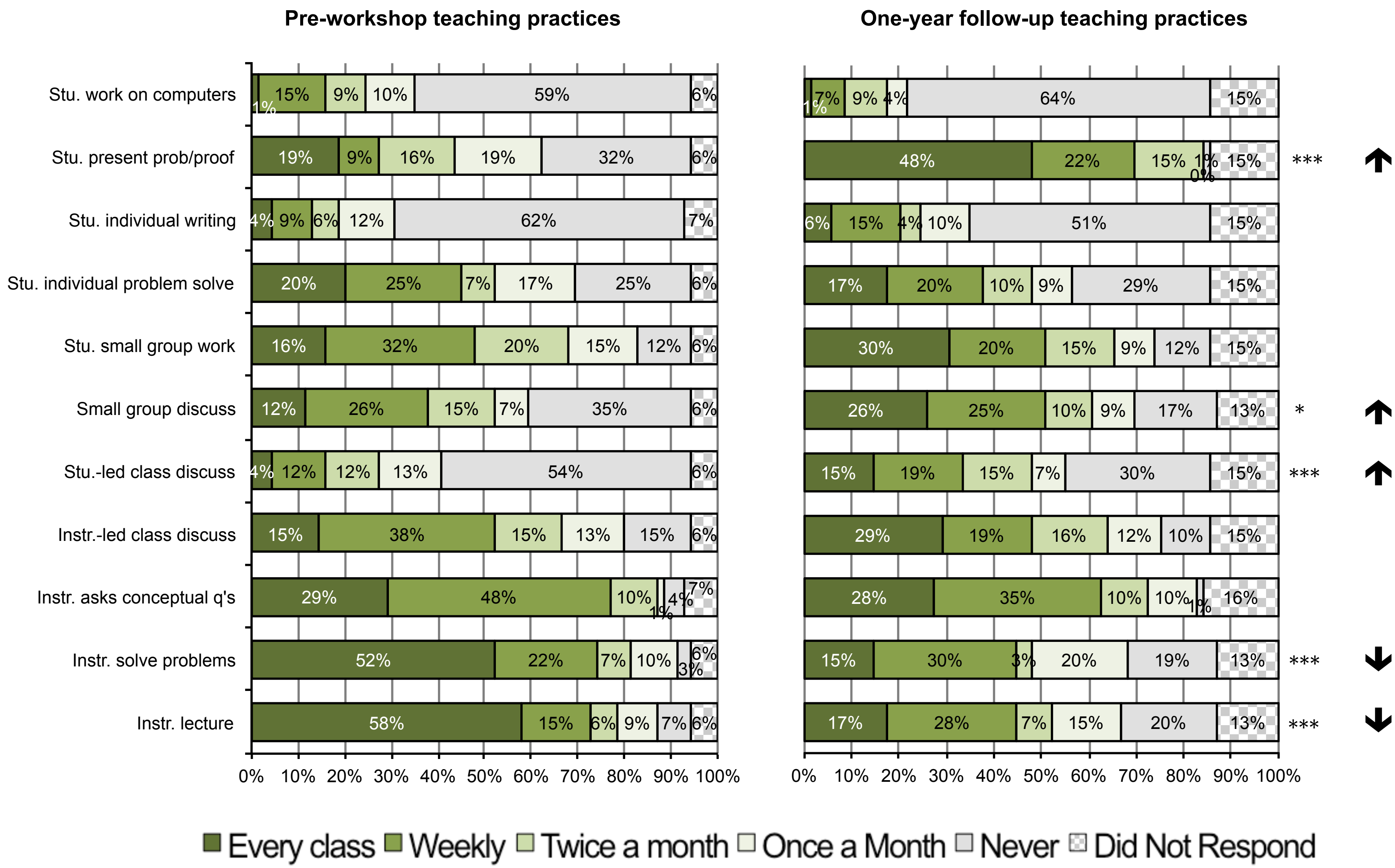
Overall, the results show marked changes in the frequency of five of the eleven teaching practices, with statistically significant changes in these from pre-workshop to the one-year follow-up that are consistent with the overall IBL implementation levels that were separately reported. Two teaching practices declined in frequency, and three increased. Below we interpret these changes in comparison with key messages delivered by the workshop.

Table 1 Significant changes in frequencies[a] of teaching practices, pre-workshop to one-year follow-up

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

[a] Frequencies 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.
*$p<0.05$, **$p<0.01$, ***$p<0.001$

Figure 1 Frequencies of pre-workshop and one-year follow-up teaching practices, matched survey responses



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

Discussion

Paulsen and Feldman's (1995) three-stage theory of instructor change, based on Lewin's (1947) theory of change in human systems, is useful for explaining the process by which instructors made a transition from traditional, lecture-based approaches to a more inquiry-based approach. The three stages of Paulsen and Feldman's model are (1) *unfreezing,* (2) *changing*, and, (3) *refreezing*. In the first stage, *unfreezing,* an instructor gains the motivation to change through seeing incongruence between his or her goals and the outcomes of his or her teaching practices. The instructor must also feel a sense of safety through "envisioning ways to change that will produce results that reestablish his or her positive self-image without feeling any loss of integrity or identity" (Paulsen & Feldman, 1995, p. 12). In the next stage, *changing,* the instructor learns, applies, and reflects on new teaching strategies to help align his or her behaviors with desired outcomes. While the instructor's strategies are fluid and changing during this stage, in the final stage, *refreezing,* either these new strategies are confirmed and solidified through positive feedback, or the instructor returns to his or her original strategies. Elsewhere (Hayward, Kogan, & Laursen, 2014; Hayward & Laursen, 2014), we discuss and interpret evidence for all three stages. However, here, we focus on stage one, *unfreezing*, and how it relates to the goal of transforming institutions.

Overall, these workshops were effective in helping instructors through this transition as they adopted IBL teaching practices. Among workshop participants there was a high rate of uptake of IBL approaches, reported directly (at least 58% of attendees), and indirectly through changes in teaching practices from pre-workshop surveys to one-year follow-up surveys. The teaching practices we measured can be sorted into three groups. ‘Core IBL’ practices are found in all variations of IBL that were communicated in these workshops, and indeed these showed significant changes in instructor use, including decreases in the use of instructor-led activities of lecturing and solving problems on the board, and increases in the use of the student-led activities including whole-class discussions, small group discussions, and student presentations of problems or proofs.

Other student-centered practices, including instructor-led discussions and students working in groups, showed non-significant increases. We considered these ‘preference IBL’ practices because they are consistent with the set of IBL approaches presented in the workshops, but are emphasized to varying degrees by different IBL instructors: for example, instructors vary in how active a role they take in leading discussions, and some use group work and group-led presentations while others have students give individual presentations of problems or proofs (Laursen et al., 2014).

Finally, instructor-reported frequencies of other forms of active learning that are not necessarily characteristic of IBL remained quite consistent from pre-workshop to one-year follow-up. These include instructors asking conceptual questions, students solving problems alone, students writing in class, and students using computers. Such methods might be included in IBL classrooms, but were not specifically addressed in any of the workshops.

These distinctions are important in light of Paulsen and Feldman’s theory of instructor change. Their theory suggests that during the *unfreezing* stage, instructors gain motivation to change when certain criteria are met, notably, psychological “safety.” This occurs when an instructor can envision ways to change that achieve his or her desired outcomes in a manner consistent with his or her self-image (Paulsen & Feldman, 1995). While changes in 'core IBL' practices were common for most participants, the ability to choose whether and how to implement 'preference IBL' practices may be important to meeting this "safety" criterion. Comments from the interviews supported this. For example, one participant was struck by "how enthusiastic everyone [at the workshop] was about teaching and helping other people learn what IBL is about and how to integrate it into your classroom," but "tuned out" one presenter that he found "aggressive" in communicating that "this is the only way to go, and that if you don't do this, then it somehow diminishes your classroom." Another participant explained that seeing IBL as a spectrum of related practices "was kind of a big moment for me because it made it seem less scary. …Feeling like I can pick and choose aspects of it, and find something on the spectrum that I feel comfortable with, was empowering."

These findings suggest that portraying IBL as a broad, inclusive set of practices, rather than a prescriptive, rigid method, may be essential for helping new instructors during the *unfreezing* stage, as it helps them to envision a way to change their teaching that is consistent with their own self-image and thus feels safe. This also gives participants the freedom to use a "hybrid" style where they incorporate some IBL strategies into a more traditional class, which may serve as a more feasible and less daunting entry into IBL, but may then lead to "full IBL." Biology education researchers have called this process "phased inquiry" and suggest that it is "an important step toward expanding adoption of inquiry practices in college science courses" (Yarnall & Fusco, 2014, p. 56). However, further longitudinal research is needed to explore how teaching practices change after instructors take these initial steps to incorporate "hybrid" IBL.

In addition to portraying IBL as a broad, inclusive set of practices, it was also important to show IBL being used in a variety of settings. Interview participants described a number of situational factors that led them to vary the IBL strategies they used, depending on the level of the class (first-year, sophomore, etc.), the size of the class, or the audience (mathematics majors, pre-service teachers, etc.). As one interview participant explained, seeing a diversity of IBL practices portrayed at the workshop, as well as a diversity of practitioners and situations, was important because it was "frustrating" when one presenter "had so many resources at their disposal that the rest of us didn't have. …how many graders and TAs they have and how they keep the class size small. These were things that just don't apply to most universities." Other participants made positive comments about the diversity of opinions and viewpoints, such as one who identified the best aspect of the workshop as offering

> *A good diversity of ideas and approaches, which I feel that I can adapt to my own teaching. As an inexperienced IBL user, I was very interested in learning from experts, but I was also interested in meeting people in my situation, who I can identify with, and hearing how they have worked through the same problems that I have.*

From their studies of physics education reform, Henderson and Dancy (2008) recommend providing instructors with easily modifiable curricular materials, so that individual instructors may use their expertise to adapt the materials to their own local environments. While their recommendation applies to reforms focused on curricular materials, our findings suggest that this feature of easy portability may also be important for sharing primarily pedagogical strategies such as IBL. Showing diverse examples of IBL may help participants to see how to customize IBL for their individual context and thus make implementation more likely.

Understandably, presenting a variety of approaches may cause concerns with fidelity of implementation. Studies in both physics (Dancy & Henderson, 2010) and biology (Yarnall & Fusco, 2014) have reported that instructors often adapt and modify research-based teaching strategies, usually in ways that align more with traditional methods and reduce the amount of student inquiry. However, IBL may be more robust to variation, as student outcomes are improved over traditional courses despite notable variations in how IBL is implemented (Laursen et al., 2014). It may be the case that portraying IBL as a spectrum of related practices helps participants by outlining ways in which they can modify the methods to fit their context while still maintaining the core features of IBL, including high levels of student inquiry.

Therefore, professional development that communicates broad, inclusive definitions of IBL in mathematics seems to help transform teaching practices in three ways: it (1) lowers the initial resistance and increases psychological safety by allowing for comfortable, personalized approaches, (2) allows for increasing adoption over time through "phased inquiry," and (3) helps to maintain fidelity through outlining modifications that preserve the core principles of the approach. Communicating broader, more inclusive definitions of student-centered strategies in other STEM disciplines may help instructors to adapt these methods to their classes while maintaining high levels of student inquiry.

Conclusion

Due to the central role of mathematics in many college majors, improving mathematics instruction by fostering broader uptake of IBL and similar research-supported teaching strategies can have positive ramifications for a very large number of students. Across disciplines, workshops are seen as an effective professional development strategy. In fact, NSF program directors interviewed by Khatri and colleagues (Khatri et al., 2013) regard “multi-day, immersive experiences with follow-up interaction with the PI as participants implement the new strategy” as the most effective propagation strategy for educational innovations, and a recent report on improving engineering education lists faculty development as a critical strategy (Jamieson & Lohmann, 2012). Indeed we found support for this view in the form of evidence that these multi-day, immersive workshops contributed to high rates of implementation, especially when paired with strong and collegial follow-up support.

Communicating broad, inclusive definitions from a diverse group of workshop organizers is also important and clearly related to the impact of these workshops on participants’ adoption of IBL teaching approaches. Communicating broad, inclusive definitions of student-centered teaching strategies in any discipline may help to reduce the initial resistance to adoption, lead to increased adoption through “phased inquiry,” and help to maintain fidelity of implementation by providing options for how instructors can adapt the strategies to fit their own classes while maintaining high levels of student inquiry. Transformation efforts that are inclusive and allow for context-appropriate modifications will likely experience broader success than those that are restrictive and inflexible.

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