Helping instructors to adopt research-supported techniques: Lessons from IBL workshops

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Abstract

Inquiry-based learning (IBL) is a research-supported form of active learning in mathematics. While studies continually show benefits of active learning, it is difficult to get faculty to adopt these methods. We present results from a set of intensive, one-week workshops designed to teach university mathematics instructors to use IBL. We use survey and interview data to explore why these workshops successfully got many participants (at least 58%) to adopt IBL. Results are framed through a three-stage theory of instructor change developed by Paulsen and Feldman (1995). We focus specifically on the first stage, 'unfreezing.' In this stage, instructors gain the motivation to change, so these findings may provide the most useful lessons for helping more instructors to adopt research-supported instructional strategies. One of the key factors for the high adoption of IBL was portraying it broadly and inclusively in a variety of contexts, rather than as a highly prescriptive method.

Keywords: Inquiry Based Learning, Pedagogy, Professional Development

Background

Numerous studies have found benefits for the use of active learning methods in science, technology, engineering and mathematics (STEM) fields (Freeman et al., 2014). Freeman et al. (2014) stated that the benefits are so strong that, "If the experiments analyzed here had been conducted as randomized controlled trials of medical interventions, they may have been stopped for benefit—meaning that enrolling patients in the control condition might be discontinued because the treatment being tested was clearly more beneficial" (p. 4). While the evidence in support of the use of active learning strategies is strong, getting large numbers of faculty to adopt new methods is difficult (Fairweather, 2008; Henderson & Dancy, 2007; 2008; 2011). Professional development workshops are one strategy for helping instructors to adopt research-supported teaching methods. Workshops are the preferred method of National Science Foundation (NSF) program directors, particularly when they are multi-day, immersive workshops and include follow-up interaction between participants and organizers (Khatri, Henderson, Cole, & Froyd, 2013). There is some evidence to support this belief. In one study with engineering faculty, among six different types of professional development, the most strongly correlated form of professional development with instructors' use of student-centered pedagogies was workshop attendance (Lattuca, Bergom, & Knight, 2014).

In this report, we present findings from weeklong, intensive workshops designed to help mathematics faculty implement Inquiry-Based Learning (IBL) in their classes. IBL is a form of active, student-centered instruction in mathematics that helps students develop critical thinking through exploring loosely-structured problems and by constructing and evaluating mathematical arguments (Prince & Felder, 2007; Savin-Baden & Major, 2004). IBL has its roots in the teaching methods of mathematician R.L. Moore (1882-1974) (Mahavier, 1999), but the term IBL is used more broadly to include various practices which share the spirit of student inquiry

through the core features of (1) deep engagement with rich mathematics and (2) collaboration with peers (Yoshinobu & Jones, 2013).

Like most studies of post-secondary professional development workshops, we involve only volunteer participants (Bobrowsky, Marx, & Fishman, 2001). However, learning from the experiences of motivated, volunteer participants may provide valuable lessons that can then be leveraged to meet the challenge of expanding the use of research-supported teaching methods among other instructors who are initially less familiar with or less motivated to use those methods. Therefore, we explore the questions:

(1) What lessons can we take from these faculty development workshops about ways to increase the use of research-supported, active learning techniques?

(2) How might we use those lessons to motivate non-volunteers to adopt these techniques?

Conceptual Framework

Surveys and interview scripts were designed to evaluate the workshops, to learn about participants beliefs about teaching, and participants' use of inquiry-based learning strategies. Rather than impose a conceptual framework from the start, we let one emerge from the analysis. To interpret findings, we used a three-stage model of instructor change developed by Paulsen and Feldman (1995), based on Lewin's (1947) theory of change in human systems. These authors described three stages of (1) unfreezing, (2) changing, and (3) refreezing. During *unfreezing* instructors gain motivation to change through experiencing incongruence between their goals and the outcomes of their teaching practices. Key to this stage is "psychological 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,* instructors learn, apply, and reflect on new teaching strategies to help align their behaviors with desired outcomes. While teaching strategies may be fluid and changing during this stage, in the final stage, *refreezing,* either these new strategies are confirmed through positive feedback and solidified, or the instructor returns to his or her original strategies. While all three stages are important, our main focus in this paper is on how these workshops supported instructors through the *unfreezing* stage, since gaining motivation may be particularly challenging with non-volunteer participants. Elsewhere, we have discussed features of these workshops that supported participants through the *changing* and *refreezing* stages (Hayward, Kogan, & Laursen, 2015, accepted).

We also draw on Rogers' *Diffusion of Innovations* (2003) to help explain results. Rogers's widely used model views adoption of innovations as a social process in which innovations spread among social networks. Various factors affect how innovations spread and the speed at which new users adopt them. We use some of these factors to help explain findings related to the adoption of IBL practices following these workshops.

Methods

Data were collected from three workshops held between 2010 and 2012. Each of the workshops was four or five days long and featured a mixture of various activities designed to help instructors learn about IBL and prepare for implementing IBL in their own classrooms. These included activities such as presentations from IBL 'experts,' panel discussions with IBL practitioners, and video observations of IBL classes. The first and third workshops were more hands-on and provided guided work time in the afternoons. During these times, participants were able to plan for their own IBL-based courses with help from the experienced staff members. The

second workshop was more conference-style with formal presentations, and did not feature this guided work time. While the workshops were all part of a larger project, they were organized and run independently and therefore varied on the activities they used. All three workshops exemplified characteristics of effective research-based professional development that have been identified in previous literature on K-12 teacher development (Cormas & Barufaldi, 2011; Garet, Porter, Desimone, Birman, & Yoon, 2001). These included such features as active participation, engaging participants in discussions of their students' learning, and promoting participant self-reflection.

As evaluators of these workshops, we collected surveys pre-workshop, post-workshop, and one academic year later. Of the 139 participants at the workshops, 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 individuals' surveys across the three time points. We successfully matched 100 (80%) post-surveys to pre-surveys and 69 (72%) follow-up surveys to pre-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.

The surveys included quantitative items and open-ended questions aimed at both evaluating workshop delivery and understanding the impact the workshops had on the participants' teaching methods. Items were developed to monitor participants' self-reported knowledge, skills, and beliefs about inquiry-based learning, as well as their motivation to use inquiry methods and their perceptions of the overall quality of the workshop. For example, on all three surveys, participants assessed their current knowledge of IBL on a scale of 1 to 4 (1=None, 2=A little, 3=Some, and 4=A lot).

To measure impact of the workshops on their subsequent teaching, we asked participants to report both *directly* and *indirectly* whether or not they had implemented IBL. We measured implementation *directly* through a multiple-choice question on the follow-up survey asking participants if they had implemented no IBL methods, some IBL methods, one full-IBL course, or more than one full-IBL course. We measured IBL implementation *indirectly* through comparing changes in participants' reported frequencies of use of eleven specific teaching practices that were probed on both pre-workshop and follow-up surveys. Available research indicates that self-report is most accurate when it is retrospective over a clearly defined time frame, when it is confidential, and when it is behavioral rather than evaluative (Desimone, 2009). Therefore, we designed these *indirect* measures of teaching practice to ask participants to anonymously report their frequency of use of eleven behaviors in a course that they had taught recently. The eleven behaviors included some that are consistent with inquiry-based learning as presented at the workshops, other behaviors that are characteristic of other forms of active learning but not necessarily IBL, and some that are characteristic of lecture-based instruction.

Open-ended questions addressed the perceived costs and benefits of using inquiry strategies and participants' impressions and learning from the workshop, which helped to provide more detail and deeper understanding of the factors that affected their use of IBL practices. Additionally, participants reported personal and professional demographic information such as career stage, institution type, gender, race, and ethnicity, so that we could test for possible differences in results among groups.

Survey data were analyzed using SPSS v. 21 (IBM Corp., 2012). Descriptive statistics were calculated for all variables, and inferential statistics were calculated as appropriate. Open-ended responses were entered into Microsoft Excel (Microsoft, 2011) and coded for common themes.

In addition, we conducted sixteen interviews. During these interviews, we asked questions to gain a deeper understanding of participants' development as instructors, their views on teaching and learning, and more detail about their classroom activities and the factors that affected whether or not they implemented IBL. Interviews were semi-structured so that participants could reveal their own perspectives instead of fitting their responses into categories introduced by researchers. As a result, we did not ask questions in the same order or with the same wording in every interview. Some topics arose spontaneously and thus were not represented in every interview. We used these interviews to help explain findings from the surveys.

Interviews were audio recorded, transcribed verbatim, and entered into *NVivo* v. 9 (QSR International Pty Ltd., 2010). We carefully read through all of the transcripts and identified recurring topics. Then, we identified segments of the transcripts that related to these topics and assigned them a code to identify that topic. If an individual passage covered multiple topics, we assigned multiple codes. Topics were coded each time they were discussed, so a code was sometimes used multiple times over the course of an interview. Groups of codes that shared similar themes were organized into domains (Spradley, 1980).

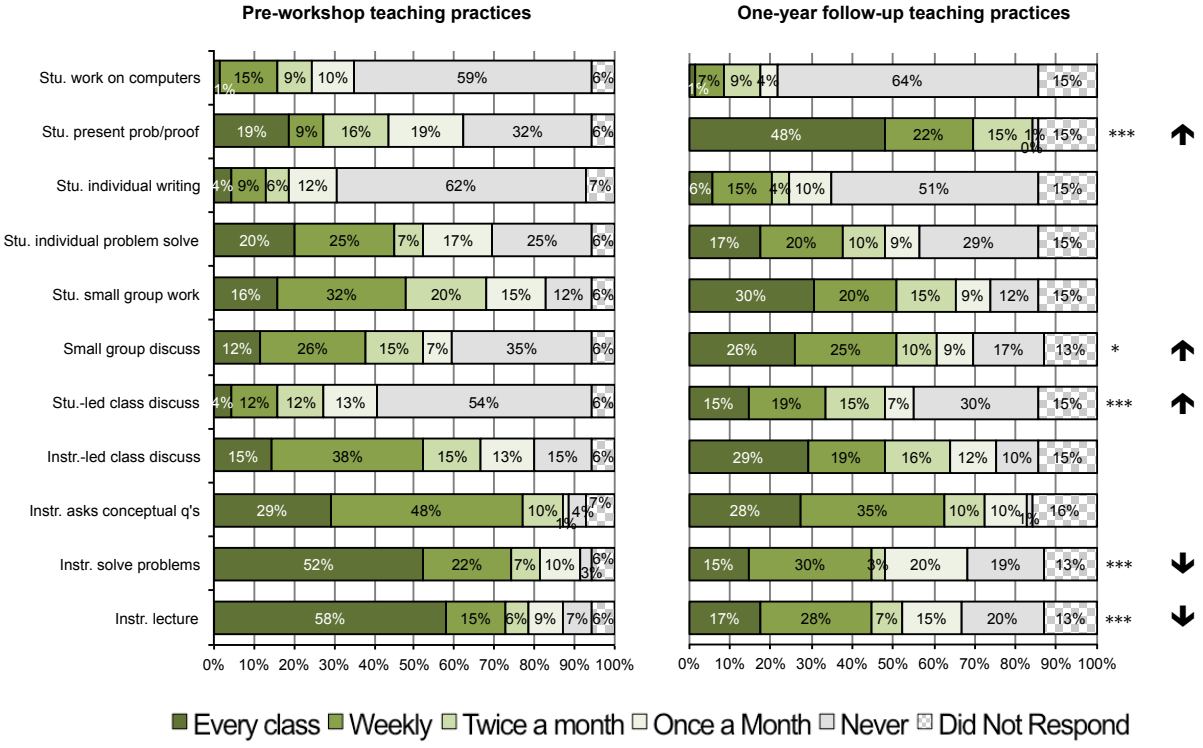
Results

Overall, the workshops were successful in helping participants to adopt IBL techniques. On a *direct* question on the follow-up surveys, 58% of all participants reported using IBL in their own classrooms, with 28% using "some IBL methods", 14% teaching "one full IBL course," and 15% teaching "more than one full IBL course." Only 8% did not report using any IBL methods, and the remaining 34% did not respond (to either the entire survey or just this question). To assess implementation of IBL *indirectly,* we compared respondents' reported teaching practices prior to the workshop with those reported on the one-year follow-up. We have presented at RUME before about the issues related to measurement and why we believe we can draw conclusions from these two types of self-reported data (Hayward & Laursen, 2014).

Significant changes in teaching practices were consistent with the use of the 'core' practices of inquiry-based learning: decreases in the reported frequencies of use of instructor lecturing and instructor solving problems or examples on the board; increases in the reported frequencies of use of student-led whole class discussions, small group discussions, and students presenting problems or proofs at the board. 'Preference IBL' practices, which instructors implement to varying degrees, showed non-significant changes. These included practices such as students working in small groups and instructor-led discussions. IBL instructors vary on whether or not they use group work and how active they are in leading discussions. Other forms of active learning that are not characteristic of IBL remained stable over time. These included students using computers or writing individually in class. Full results are presented in Figure 1 below.

These results corroborate participants' self-reported level of IBL implementation (none, some, full-IBL). The patterns related to core, preference, and non-IBL practices are also important in the context of Paulsen & Feldman's *unfreezing* stage. Key to *unfreezing* is the idea of 'psychological safety,' or being able to envision ways to change that fit with the individual's identity as a teacher. At the workshops, IBL was presented as a broad range of related practices that share common features, rather than prescriptive techniques or curricula. Having options for 'preference IBL' practices helped provide psychological safety as it allowed participants to implement a type of IBL that fit with their own teaching style. The *unfreezing* stage is especially relevant for spreading research-supported practices beyond volunteers, who are willing and able to commit to an intensive workshop.

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

In the interviews, ten of the sixteen participants commented on the presentation of IBL as a range of related practices. They explained how this broad presentation of IBL provided psychological safety. 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" (Male participant, cohort 2). 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" (Female participant, cohort 2).

This concept of a "spectrum" of IBL was particularly powerful for some participants who were familiar with other instructors who employ the teaching model of R.L. Moore "dogmatically." For example, one participant explained that,

> *the Moore method is on one extreme and I think when I was deciding whether or not to use IBL in my classes before the conference, I had always viewed it as all or none. I hadn't realized that some of the projects and stuff that I'd been doing in my classes were IBL in nature and that that's okay, that you don't have to do an entire class inquiry-based, or that you don't have to be as rigid as the Moore method prescribes (Female participant, cohort 2).*

Other participants also mentioned this idea of not doing 'full IBL' courses, but instead starting with smaller steps and then building over time. One participant explained that this was because "you saw people doing full inquiry classes, and it seems very intimidating, very

time consuming. …You don't have to go to a full inquiry class … as the different semesters go on, I'm planning on turning more and more into inquiry" (Female participant, cohort 1).

In addition to portraying IBL as a broad, inclusive set of practices, the workshops also showed IBL being used in a variety of settings. For example, workshops featured sessions about how to tailor IBL to different groups of students (such as first-year students and pre-service teachers) and in different types of courses (such as calculus and proof-based). These differences shaped how interview participants structured their IBL courses. Interviewees 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.). All sixteen interviewees commented on these situational factors a total of 101 separate times throughout the interviews, meaning that they often considered multiple factors in designing their courses.

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" (Female participant, cohort 2).

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 (Male participant, cohort 1).*

Another participant felt that the workshop "gave me more ways and more tools to introduce IBL into [lower level and pre-service courses]" (Male participant, cohort 2). As a result, he was able to incorporate IBL methods into classes he previously thought could not be taught with IBL.

Application/Implications to Future Research or Teaching Practice

These findings suggest that the workshop leaders' choice to portray IBL as a broad, inclusive set of practices, rather than as a prescriptive, rigid method, may have been essential for helping new instructors during the *unfreezing* stage, as it helped them to envision a way to change their teaching that was consistent with their own self-image and thus felt safe. This also gave participants the freedom to use a "hybrid" style where they incorporated some IBL strategies into a more traditional class. This may have served as a more feasible and less daunting entry into IBL, but may then lead to "full IBL" as instructors experience success and observe positive student outcomes.

Using broader, more inclusive portrayals may also help increase the adoption of other research-supported strategies. Particularly, it may help instructors to start small and increase the use of these innovations over time. There is already evidence for this outside of mathematics. Biology education researchers call 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). "Phased inquiry" may be useful for overcoming time constraints, which physics instructors cite as one of the biggest barriers to implementing research-based instructional practices (Dancy & Henderson, 2010). Communicating broad definitions may help instructors to learn and phase in new strategies piece-by-piece over time, which may in turn

make time seem like less of a barrier to implementation. In Rogers's (2003) model, *trialability* is positively related to the rate of adoption of innovations. However, further longitudinal research is needed to explore how teaching practices change after instructors take these initial steps to incorporate "hybrid" methods.

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 helped participants to customize IBL for their individual context and may have made implementation more likely. Rogers (2003) calls this process *re-invention* and states that it may reduce mistakes, help to fit innovations to local contexts, and help to make those innovations more responsive to changing conditions.

The workshop leaders' choice to present IBL as a variety of related approaches may have been inviting for participants, but may cause others to doubt whether the fidelity of IBL was maintained. Studies in both physics (Dancy & Henderson, 2010) and biology (Yarnall & Fusco, 2014) have reported that instructors often adapt and modify research-based instructional strategies, usually in ways that align more with traditional methods and reduce the amount of student inquiry. Instructors often change materials to match their own individual style and preferences, because they do not expect materials created elsewhere to work without modification (Henderson & Dancy, 2008).

However, there are various ways to measure fidelity of implementation, which can be categorized into 'fidelity of structure' (i.e. adherence and duration of use) and 'fidelity of process' (i.e. quality of delivery, and program differentiation, or whether the "critical features that distinguish the program from the comparison condition are present") (O'Donnell, 2008, p. 34). For pedagogical innovations like IBL, fidelity to process may be more important whereas curricular reform may focus more on fidelity to structure. IBL, specifically, may be somewhat robust to variation in structure, 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 helped participants by outlining ways in which they could modify the methods to fit their context while still maintaining the fidelity of the core features of IBL, including high levels of student inquiry. If research-supported active learning strategies are defined in a way that allows for and helps to outline appropriate modifications, this may be important to maintaining the fidelity of their core features (fidelity of process) and promote the same positive outcomes supported by the research.

Evidence from our study of this example of professional development of IBL that communicates broad, inclusive definitions seemed to help transform teaching practices in three ways: it (1) lowered the initial resistance and increased psychological safety by allowing for comfortable, personalized approaches to IBL teaching, (2) allowed for increasing adoption over time through "phased inquiry," and (3) helped to maintain fidelity to IBL's core features through outlining modifications that preserved the core principles of the approach. Our findings suggest that research-supported innovations that are inclusive and allow for context-appropriate modifications are likely to support broader adoption and greater user success than those that are restrictive and inflexible.

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