Navigating the Straits:
Critical Instructional Decisions in Inquiry-Based College Mathematics Classes

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Abstract

Inquiry-based learning (IBL) approaches engage college mathematics students in analyzing and solving problems and inventing and testing mathematical ideas for themselves. But to effectively apply IBL teaching methods, instructors must make good decisions both in planning their syllabus, assignments, and assessment before the term begins, and in the moment, as they monitor classroom progress, manage interpersonal dynamics, and decide what to do when things do not go as planned. Using interview data from 40 IBL instructors at four campuses, including graduate teaching assistants and faculty at a range of experience levels, we identify critical instructional decisions that can affect the success of IBL classes. We describe why these decisions are more salient in IBL classrooms than in those using lecture-based methods, and we examine patterns in instructors' ability to identify these issues for themselves and suggest appropriately nuanced solutions to common IBL classroom dilemmas.

Keywords: inquiry-based learning, teaching assistants, faculty, qualitative methods, instructional methods

Introduction

The term inquiry-based learning (IBL) is used to describe approaches to college mathematics that place student discovery of mathematical ideas at the center of the classroom. Rather than emphasizing rote memorization and computation skills, IBL methods seek to help students develop critical thought processes by exploring ill-defined problems, applying logic, making and analyzing arguments. Moreover, by building students' confidence in their abilities to generate and critique ideas and to solve problems independently, IBL methods help to foster students' creativity, persistence and intellectual growth (e.g., Buch & Wolff, 2000). Like "discovery learning" (Bruner, 1961), "problem-based learning" (Savin-Baden & Major, 2004), and other "inductive teaching" approaches (Prince & Felder, 2007), IBL invites students to work out ill-structured but meaningful challenges. In mathematics, IBL approaches are often derived from the work of Texas mathematician R. L. Moore, but while Moore emphasized individual learning, modern implementations of IBL in mathematics draw importantly on social learning perspectives (e.g., Lave & Wenger, 1991; Vygotsky, 1978).

Our research group has studied IBL classrooms at four university "IBL Centers" funded by a private foundation. Since 2004, a cadre of faculty on each campus has been engaged in developing inquiry-based undergraduate mathematics courses for upper- and lower-division mathematics majors, science and engineering students taking math as a cognate, and pre-service teachers. These courses engage students in creating, exploring and communicating mathematical ideas, guided by faculty and critiqued by peers. Our large, mixed-methods study of these courses includes two years' of survey, interview, and test data from over 100 discrete class sections, and

academic records from over 6000 students. Much of our study focuses on student outcomes of IBL courses; here we highlight instructors' experiences in teaching IBL mathematics courses.

Methods

Interviews were conducted with 40 IBL instructors at four campuses,18 graduate student teaching assistants (TAs) and 22 faculty. The general term 'instructors' recognizes the range of classroom roles represented; some graduate students were lead instructors, and others, though nominally TAs, had more IBL teaching experience than did their faculty member. Faculty included pre-tenure, tenured, non-tenure-track, and visiting (postdoctoral) faculty. The semi-structured interview protocol established instructors' career status and IBL involvement; explored instructors' teaching style, beliefs, and specific classroom practices; and asked for their observations of student learning gains (or lack of gain) and personal or professional benefits and costs to themselves. Most of the interviews were conducted in person; a few were done by phone. Interviews of 45-70 minutes were digitally recorded and transcribed *verbatim*. These data are complemented by a set of individual and focus group interviews with 68 IBL students.

The text data were coded using a mix of inductive and deductive codes. A total of 164 codes were generated under six main domains (Spradley, 1980). Instructors' observations of student learning gains and learning processes were coded using a scheme previously developed for coding student data, so that these two data sets could be compared. Instructors' reports about their own teaching practices, context, and educational beliefs, and about the outcomes of IBL teaching for themselves and their departments, were coded and subjected to taxonomic analysis to develop sub-categories and identify analytical themes. Here we focus on the broad category of codes labeled as "teaching processes"; this category included 14 subcategories and constituted the bulk of the coded data, over 900 coded passages or individual instructor observations.

Findings

In interviews, instructors often told us in copious detail about specific practices, such as how they graded homework assignments, how they assigned class participation points, or how they selected students to present at the board. After puzzling for a while over the evident importance of these details to instructors, we came to recognize that, collectively, these reports delimited a shared set of teaching concerns. Each instructor described an idiosyncratic practice developed for a particular course, student audience, and personal style, and seldom couched these in philosophical terms; but as analysts, we could abstract from these narratives the teaching dilemmas that every instructor had to resolve. The general issues do not differ from those encountered by more traditional instructors—choices about curriculum, classroom atmosphere and management, and student assessment. But for IBL instructors, these become "critical instructional decisions" that are especially salient for several reasons:

- Most decisions become *more explicit*: Traditional teaching may be based on received wisdom held by both students and instructors, often unquestioned, about how things are or should be. Instructors may not have faced these choices explicitly in prior teaching.
- Decision-making becomes *more dynamic*: With class activities and pacing often in students' hands, IBL instructors must respond in the moment rather than follow prepared notes. This requires alertness to the classroom atmosphere and attention to student responses.
- Some aspects of class are *more sensitive* to teaching decisions: Because IBL classrooms rely more on collaborative learning, decisions that affect student participation and the classroom

atmosphere may have greater consequences for the success of a course. Choices about these factors intersect extensively with issues of individual accountability and work load. With greater responsibility for everyday work, students' need for available and appropriate help can become more acute, affecting the use and tenor of office hours.

- Some issues require that *new solutions* be found: As learning goals shift away from content coverage and toward skills such as constructing and communicating mathematical arguments, past solutions (e.g., assessing learning by timed, individual tests) may no longer measure what instructors value or may not mesh well with students' experience of the class as a whole.

We will present a research-based framework, drawn from the interview data, that organizes the critical decisions that IBL instructors must make in designing and running their courses, including setting the tone and expectations for students; managing interpersonal dynamics; balancing student accountability and participation; setting curriculum; and evaluating student learning. We will use examples from student and instructor interviews to show how and why instructors' decisions on these points become critical for the effectiveness of an IBL class. In some cases, the decisions are highly interdependent. For example, practices intended to increase student accountability for the homework that is the basis of the next day's class work can make it difficult to establish a positive and collaborative classroom atmosphere, but too little attention to accountability can lead to student over-dependence on others to do the work and thereby reduce the level of class participation. The instructor is thus easily caught between a rock and a hard place—the straits noted in the title.

The interview data also indicate some group differences in instructors' decision-making. For example, local "styles" of IBL teaching on each campus affected the choices that instructors made. Sometimes these shared styles meant that colleagues were good sources of teaching advice and wisdom, but sometimes they also constrained the solution space, restricting the range of teaching choices that were seen as possible or desirable. Instructors also varied in their ability to identify critical classroom issues for themselves. TAs in particular were often able to identify subtleties in how classroom decisions affected student behavior. For example, in explaining "what worked" or did not work in their classroom, TAs were more likely to offer explanations that hinged on the nature of instructional decisions or the quality of their implementation, while faculty more often gave explanations in terms of student characteristics, such as work ethic, ability and preparation. TAs' distinctive perspective appeared to arise from multiple sources: their dual classroom roles as teachers and observers; their nearness to the student experience—both as recent undergraduates themselves and from direct work with students in office hours or help sessions; and their lower identity investment in the perceived success of the course.

Previous studies have taken a close look at particular instructors' practices in one or two classrooms (e.g. Weber, 2004; Rasmussen & Marrongelle, 2006). Here, by examining the practices of a large sample of teachers and across a wide range of IBL styles, we establish that certain teaching issues are quite commonly confronted by IBL instructors. Knowing *what* these issues are, and how they appear to mathematics instructors, we have the chance to better understand *how* particular instructional choices may affect student outcomes in positive or negative ways. The findings thus contribute to the small existing body of empirical research on the "unexamined practice" of college mathematics teaching (Speer, Smith & Horvath, 2010). Lastly, our findings have significant practical implications for designing professional development to increase the uptake and improve the implementation of IBL methods across the

U.S. We seek to develop a framework that can help IBL instructors consider and analyze their instructional decisions, and predict (or at least attend to) the classroom consequences of their choices; and that can provide them with a common language to recognize shared problems and swap solutions despite differences in student audience, course content, and institutional setting.

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