Organizational features that influence departments' uptake of student-centered instruction: Case studies from inquiry-based learning in college mathematics

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Active learning approaches to teaching mathematics and science are known to increase student learning and persistence in STEM disciplines, but do not yet reach most undergraduates. To broadly engage college instructors in using these research-supported methods will require not only professional development and support for individuals, but the engagement of departments and institutions as organizations. This study examines four departments that implemented inquiry-based learning (IBL) in college mathematics, focusing on the question, "What explicit strategies and implicit departmental contexts help or hinder the uptake of IBL?" Based on interview data and documents, the four departmental case studies reveal strategies used to support IBL instructors and engage colleagues not actively involved. Comparative analysis highlights how contextual features supported (or not) the spread and sustainability of these teaching reforms. We use Bolman and Deal's (1991) framework to analyze the structural, political, human resource and symbolic elements of these organizational strategies and contexts.

Keywords:
Inquiry-based Learning, Departments, Case Studies, Reform, Teaching Assistants (TA)

Research evidence supports the use of student-centered teaching approaches to improve student educational outcomes in science, technology, engineering and mathematics (STEM) disciplines (Freeman et al., 2014; Singer, Nielsen & Schweingruber, 2012; Ruiz-Primo et al., 2011). The bottleneck in achieving these improvements on a national scale is not a lack of well-developed classroom approaches from which to choose, but rather slow faculty uptake of these proven teaching methods (Fairweather, 2008). This paper focuses on the important but under-studied organizational context for uptake, by examining the implementation of inquiry-based learning (IBL) at four research university mathematics departments. We address the question,

> *What organizational factors, including both explicit action strategies and inherent contexts, influence the spread and sustainability of inquiry-based learning in mathematics departments at US research institutions?*

Conceptual Framework

On the whole, prior studies of the uptake of student-centered teaching approaches have focused on individual STEM instructors, examining their knowledge and skills around instruction, and the internal and external barriers to pedagogical change that they face (e.g. Henderson & Dancy, 2007; Walczyk, Ramsey & Zha, 2007). Early disciplinary socialization inculcates a values hierarchy that privileges research over teaching and portrays teaching as an art or innate talent rather than a craft that can be studied, learned and mastered. Structural issues such as classroom seating arrangements complicate the logistics of methods such as small group work, and instructors fear real or perceived resistance from their students, colleagues, or chairs. In general, this focus treats teacher decision-making as individualized within a static setting.

However, STEM instructors are also embedded in dynamic social systems that influence their thinking in positive and negative ways (Austin, 2011). Thus it is also important to

understand instructors' working contexts in higher education. Contextual influences at the *institutional level* include features such as overall teaching loads, the relative weight of teaching duties relative to research and service in faculty job descriptions, and the role and measurement of teaching outcomes within faculty reward systems. These may vary widely, for example, between a research-oriented institution and a liberal arts college.

These institutional influences are commonly manifested at the *department level*, where curricular structures are set and teaching assignments are made. Here colleagues communicate formal traditions and informal norms about teaching, shaped by their understanding of their student clientele and in turn reinforced by students' expectations. For example, the type of teaching seen as appropriate in "service" courses may be different from that in "majors" courses. Collegial agreements—stated or tacit—may inform expectations about the nature and amount of work that can be assigned, availability and use of office hours, and specific topics that must be covered as preparation for the next course in a sequence. Department chairs and committees control access to resources and rewards, and oversee graduate students' preparation as teachers.

Finally, *disciplinary contexts* shape instructors' understanding of the aims of education in their field, their notions of intellectual development and rigor, and their professional identities as researchers and educators (e.g., Brownell & Tanner, 2012). In mathematics, phrases such as "mathematical maturity" encode and signal the value of generalized skills in analyzing problems and developing solution approaches, creativity, flexibility, and recognition of mathematical concepts in varied contexts. Epistemological beliefs about the nature of knowledge and "truth" shape instructors' interest in and ability to make sense of education research findings about teaching and learning that rely on different disciplinary standards for what counts as knowledge.

In addition to considering the level at which these organizational influences are felt, we apply Bolman and Deal's (1991) multi-frame model to analyze their nature. In this model, four main perspectives serve as viewpoints for examining organizational issues: structural, human resource, political, and symbolic perspectives. Each of these perspectives functions as a frame or "lens" that can "bring the world into focus" (p. 11) in order to understand organizational issues—in this case, processes of change to support faculty use of research-based instruction.

- The *structural* frame emphasizes policy and procedure as tools for shaping instructor practice. This lens recognizes the importance of formal rules, policies, management hierarchies, and relationships within organizations.
- The *human resource* frame emphasizes the importance of the demographics, experiences, needs, and feelings of the people involved in an organization. Here the key human resource is the instructors who carry out the department's teaching mission, including both those who engage with the IBL Center's teaching reforms and those who do not.
- The *political* frame attends to issues of resource allocation and the sources and seats of power, whether tied to formal institutional roles or as informal thought leaders of high status.
- Finally the *symbolic* frame focuses attention on issues of meaning and culture within an organization, including rituals, stories, and celebrated individuals, and the process through which sense-making takes place within the organization (Eckel, Green, & Hill, 2001).
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Study Methods

Context of the Study

This report draws upon a large, mixed-methods study examining inquiry-based learning (IBL) in four mathematics departments where privately funded "IBL Centers" had been established to promote the use of IBL in teaching. These highly ranked research departments

were assumed to have high visibility and influence in their discipline. All four were "very high" research schools by Carnegie classification and had full-time, four-year, selective undergraduate programs with low transfer rates. Each Center was led by an eminent mathematician with some track record of involvement in K-12 or undergraduate education.

The full study encompassed a wide range of issues, including student outcomes of IBL instruction and IBL teaching and learning processes, but in this report we focus on instructors' experiences in implementing IBL. Our analysis treats each department as a case, but also identifies common issues across the four cases that help to highlight challenges and opportunities for establishing and sustaining student-centered approaches to teaching in college mathematics.

Study Samples and Analysis Methods

This report draws primarily on qualitative analysis of 42 semi-structured interviews with 43 IBL instructors (one focus group had two teaching assistants from the same course). We use the general term 'instructors' to refer to all interviewees; when it is important to distinguish specific classroom roles, we specify "faculty" (anyone in the lead instructor role, regardless of appointment type) or "TA" (graduate student in a course assistant role).

The interview sample was drawn from institutionally provided lists of active or previous instructors of IBL courses for the period 2006-2009. We invited all instructors we could reach and scheduled in-person interviews during campus site visits in 2009, or telephone interviews if needed. The overall response rate was 77%, varying from 50% to 88% by campus. Nearly all interviewees were white; about 15% were born outside the US. Most taught "math-track" courses for math or STEM majors; seven taught IBL courses for pre-service teachers.

The faculty interview subset included 23 interviewees (3 women, 20 men) who held faculty appointments, including tenured, pre-tenure and non-tenure-track instructors in both long-term lectureships and short-term postdoctoral or visiting positions. Of these, 13 had prior IBL teaching experience of one year to decades, and 10 were new to IBL.

The TA interview subset included 20 teaching assistants (9 women, 11 men). Most were second- to seventh-year graduate students; at the time of the interview a few had graduated and moved on to postdoctoral or tenure-track faculty positions. Their IBL teaching experience ranged from one term to several years.

The interviews covered a range of topics and questions about IBL instruction, student outcomes, and the relationship of IBL teaching to the interviewee's career path. All protocols were approved by the Institutional Review Board, and interviewees provided informed consent.

Formal content analysis methods were used to analyze the interviews (Babbie, 2001; Berg, 1989). Digitally recorded interviews were transcribed verbatim and coded using *NVivo 8.0* (QSR International, 2009). The coded passages reflect a set of analytical themes that together describe the nature and range of issues in participants' collective report. Counting the frequencies with which different themes appear helped to characterize the relative weighting of these issues.

In all, about 2400 text passages were coded into five broad themes, each with 8-14 sub-themes, divided roughly as follows (counted as a percentage of all coded passages):

- observations of cognitive, affective and other outcomes of IBL for students – 16%
- students' learning processes that instructors observed or hypothesized – 16%
- instructors' reflections on the processes of teaching – 40%
- personal and professional outcomes of IBL teaching for instructors – 16%
- instructors' personal, departmental, disciplinary and institutional contexts – 10%

The present analysis focuses on these latter, context-focused codes, with some use of respondents' comments on teaching and learning processes and their own professional outcomes. Documents about the IBL Centers (e.g., annual reports to their funder) were used to elucidate or confirm some of the contextual features identified from interviews.

In addition, data from classroom observation (over 300 hours) in 42 course sections, as well as data from student surveys (1105 respondents) and interviews (68 respondents), provide context on campus-level patterns and variations in how IBL was conceived and executed in the classroom. These data primarily address the learning outcomes and learning processes observed in class and reported by students; insights from these data enrich this report but are not its focus.

Study Sites: Commonalities and Variation in IBL Instruction

As context for this analysis, we describe common features of IBL instruction and identify some sources of variation among them. We have described IBL instructional practices as applied in the IBL Centers elsewhere (Laursen, 2013; Laursen et al., 2014); the practices we observed at the Centers are consistent with those reported by practitioners in the broader IBL community (e.g., Yoshinobu & Jones, 2013; Coppin, Mahavier, May & Parker, 2009). Key features of these IBL classes were identified from classroom observation, course documents, and instructors' and students reports in surveys and interviews:

- Students solve challenging problems alone or in groups; they share their solutions, then analyze, critique and refine their solutions.
- Class time is used for these student-centered activities. Students often lead the activities (e.g. by presenting their work) and these activities change several times a class period.
- The course is driven by an instructor-built sequence of problems or proofs, rather than by a textbook; the pace of the course is set by students' progress through this sequence.
- Course goals tend to emphasize mathematical thinking skills and communication practices; "coverage" of specific content is less central in the syllabus.
- The instructor's role shifts notably from "sage on the stage" to "guide on the side" (King, 1993), playing stage manager, monitor and summarizer of key mathematical benchmarks, and cheerleader for students.

The details of practice varied somewhat from course to course (Laursen, 2013) but these features were consistently noted. Class time was predominantly used for student-centered work, which accounted for over 60% of class time observed.

While instructional practice was relatively consistent, other features of the IBL courses varied widely among Centers. Each IBL Center selected the courses where it would apply IBL methods. These ranged from first-year honors courses to upper-level courses for mathematics majors and students in fields such as physics, engineering or economics. Two Centers developed IBL courses for pre-service elementary and/or secondary teachers. These selections were guided both by theoretical considerations, such as courses thought well suited to IBL approaches or student audiences thought to benefit, but also by practical considerations, such as where class sizes were already amenable to IBL techniques.

As a result, the overall range of courses and student audiences in the study was large. This reflects real-world conditions of instructional reform in higher education, where individual faculty have high autonomy in how to teach their courses and where curricular sequences and student characteristics may vary widely among departments. Indeed, this high variability within and among departments is one reason for the slower pace and different path of educational reforms in higher education as compared to K-12 education.

Study Findings

Our data reveal both explicit action strategies and implicit contextual features that shaped departments' implementation of IBL. Explicit strategies were more easily noted by interviewees, as each Center developed ways to support IBL instructors and engage colleagues, including:

- Processes to engage faculty in IBL instruction: recruiting new participants, preparing and supporting them for IBL teaching
- Processes to engage the support of colleagues not involved in IBL teaching, especially those whose approval was politically important
- Engagement of graduate TAs in IBL instruction: recruitment, professional development, and context within the department's TA teaching preparation program (if any).

Contextual features were less often recognized by interviewees themselves and instead were embedded in interviewees' statements as taken for granted. Some of these were well-established aspects of the institution, such as its size and reputation. Other features of the IBL program were sometimes the result of explicit and strategic decisions made when the Center was established, but had come to be seen as pre-existing features of the Center's IBL program that shaped how things were done. These contextual features included:

- Nature of the institution and department: size, prestige, public or private status
- Characteristics of the IBL Center's leader: status and seniority in mathematics and education, leadership style, relationships to other STEM reform efforts
- Characteristics of faculty connected to the Center's work: seniority, status, nature and extent of involvement or resistance
- Nature of the IBL undergraduate program: targeted undergraduate audiences, selection processes for entry to IBL courses, predominant styles of IBL teaching
- Other components of the IBL program, if any: pre-service and in-service K12 teacher education, mathematics enrichment for K12 students, linkages to other STEM programs.

We argue that both the explicit strategies and contextual features help to account for the spread and sustainability of IBL as a teaching reform in undergraduate mathematics in these departments. In general, IBL teaching practices spread with adequate local fidelity within these departments, despite local variation in style. We use the contrasting cases to illustrate how different strategies and cultures helped or hindered the spread and sustainability of IBL.

Understandably, many of the explicit strategies fall primarily under Bolman and Deal's (1991) *human resource* frame, especially efforts to interest colleagues in IBL and to develop their skills as IBL teachers. These included collegial and informal mentoring (more rarely, structured mentoring); participation in formal workshops (helpful albeit not widespread); and extra-departmental support from a national meeting on IBL in mathematics and the broader network of practitioners who participated in this meeting and related events. Some human resource strategies sought to build an active IBL community, for example through lunches and talks that focused on IBL and other teaching topics, to which all interested persons were invited. TAs' professional growth as teachers was greatest when they too participated in this community and when they were generally treated as full instructional partners, for example by meeting regularly with lead instructors to share observations about students and troubleshoot daily problems in the class. TAs also discussed and shared practices within their own peer group, leading to rapid uptake of certain TA-initiated innovations in grading and student motivation.

Strategies that helped to recruit and engage non-involved instructors sought to develop awareness and positive impressions of IBL among those in formal and informal leadership roles. Primarily *political* strategies included inviting colleagues to observe an IBL course or to evaluate

a graduate TA's teaching in such a course. One department made a point to share emerging research findings on student outcomes of IBL with key committee chairs, deans and provosts. One leader's style of "managing by walking around" was also a political strategy that fostered high buy-in and program coherence and alerted him to impending challenges. *Structural* strategies used existing policies and procedures to enhance visibility and acceptance of IBL, such as asking the standing undergraduate curriculum committee to review IBL courses, or engaging the department's educational thought leaders to serve as a steering committee for the Center. One department took advantage of the *symbolic* frame by successfully nominating an IBL leader for a major institutional teaching award, and by publicizing its IBL work in the department's annual newsletter sent to supporters and alumni. *Human resource* strategies that centered on building community also doubled as a means to engage non-involved instructors when departmental leaders participated or simply were informed of colleagues' participation in these events.

The culture and structure of TA preparation varied widely across the four departments, which in turn shaped opportunities for TAs to join the IBL effort. Departments differed philosophically as to whether opportunities to TA for IBL courses should be concentrated among a few to hone their IBL teaching skills, or be offered broadly to give more TAs exposure to IBL. In one case the chance to TA an IBL course was offered to all TAs moving through that department's formal, multi-part TA preparation process; elsewhere TAs were informally recruited by IBL faculty leaders. In both scenarios, TAs were carefully screened for aptitude and interest.

In practice, what commonly resulted from IBL participation by TAs and other early-career instructors (including postdocs) was a strong commitment to student-centered teaching, based on having seen it work for undergraduate students—sometimes despite their initial skepticism. Indeed, most said they would teach this way again. TAs in particular viewed IBL as a broadly applicable pedagogy, describing their enhanced skills as a nuanced "toolkit" that enabled them to apply IBL to varied student audiences. Interestingly, they often articulated a broader view of where IBL could be used than that expressed by their senior faculty colleagues. Overall, these IBL teaching experiences proved to be a powerful form of experiential professional development for early-career instructors. As they moved on to teaching roles at other institutions, they took along re-shaped teaching philosophies and expertise; many have remained active and taken on leadership roles in the larger IBL mathematics community.

Departmental cultures strongly shaped the predominant local style of IBL, as our classroom observation data make clear (Laursen et al., 2014; Laursen, Hassi & Hough, 2015). Courses at two Centers often featured formal, in-class group work, while courses at the other two emphasized student presentations at the board. These patterns occurred and persisted in part because of how instructors learned about IBL: what colleagues said about IBL, what they saw in colleagues' classrooms, and how they adopted or adapted prior versions of the same course as they prepared to teach an IBL course new to them. Because few had independent exposure to active learning approaches (e.g, via formal professional development, reading, or peers outside the Center), such informal transmission of IBL norms led to substantial homogeneity of IBL approaches in use within any one campus. However, variation *among* the Centers played a significant role in broadening understandings among the larger IBL community of "what is IBL" (Author, 2015).

Local culture also shaped views of what courses and students were seen as good fits for IBL. In considering which students would benefit from IBL, IBL was variously seen as

- a special experience to recruit talented (honors) students into mathematics

- a good way to help students make the transition from lower-division, computational courses to upper-division, proof-based courses
- a crucial experience for non-math majors (especially pre-service elementary and middle school teachers), to learn to think like mathematicians and to value IBL teaching.

These views reflect disciplinary beliefs about "who can do IBL," shaped in turn by prevailing views of "what is IBL." Some departments held multiple views and tested these various hypotheses in their choice of where to implement IBL. The choice to work with pre-service teachers was in part driven by a need to assert the department's primacy over mathematical preparation of teachers, but had a side benefit of requiring good cooperation with the School of Education, which in turn made them advocates for the IBL program.

As to mathematical content, there was little consensus as to what course content was best suited for IBL treatment; indeed, nearly every assertion about how a particular topic (e.g., linear algebra) "could not be taught" with IBL was countervailed in our data by a contrasting assertion of why that course worked very well in IBL form. Such lack of consensus in the evidence suggests that these beliefs, while informed by and often couched in disciplinary terms, were in fact department-based. It is thus noteworthy that TAs in particular could articulate broader uses of IBL, even in courses where IBL was not formally practiced in their department.

Implications for Practice

Over time, these departments have seen IBL spread and succeed within the department and beyond, as early-career trainees took their newfound IBL skills to new venues. But long-term sustainability of the IBL reforms in the home departments is less certain. A distinguished leader and a few senior faculty champion IBL courses, but overall senior faculty participation is low, and the programs rest on transient or low-status instructors such as postdocs and non-tenure-track instructors. There is some evidence of risk to programs' ongoing health when a senior leader steps down, and there has been little visible effort to absorb the costs of the IBL program.

We do not yet know whether and how these departments will sustain their IBL programs if funding is withdrawn. But in our judgment, the departments with the best prospects for sustaining their IBL programs are those which have consciously attended to the *political* and *symbolic* landscapes—by keeping key leaders in the loop, by making strong alliances with external constituencies for general education or teacher preparation, and by publicizing and promoting their work to a variety of stakeholders within and outside the department. These strategies help to broaden ownership of IBL so that the effort does not depend on a single leader.

Explicit strategies for *human resource* development have helped to strengthen student outcomes at the Centers and to enhance the spread of IBL beyond these Centers, but have had less effect on the sustainability of IBL within the department. Staffing the IBL courses with temporary instructors who develop skill and enthusiasm but then move on to other positions is a double-edged sword: it enhances the Centers' role as national leaders in IBL but fails to bolster their own long-term sustainability. Finally, long reliance on external funds—and the concomitant need to preserve the argument that these funds are essential to continued activity—seems to have limited departments' attention to *structural* aspects of sustainability. We note little sense of urgency to find other ways to cover the costs of team-teaching, maintaining small class sizes, or deploying extra TAs in IBL courses, and indeed there may be some risk to doing so. We acknowledge, however, that our data set is most limited on this point.

Overall, we propose that the set of action strategies must be well-rounded to enhance the growth, success and sustainability of an education reform within a department. Human resource

strategies are necessary but not sufficient; program sustainability requires explicit attention as well to political, symbolic and structural elements of the organization. These strategies must also be designed to fit the department's unique context. Higher education is rife with stories of once-promising reforms that failed to take hold; analyzing these organizational features may be important in understanding why.

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