Tracking the Spread of Research-Based Instructional Strategies

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Abstract—The adoption of research-based instruction strategies (RBIS) by faculty is generally perceived as being slow. Faculty resist change, reject data that demonstrates the effectiveness of RBIS, and prioritize research over teaching. Even when faculty attempt to use RBIS, they often do so with poor fidelity to the original design of the RBIS. By organizing faculty into communities of practice, we are observing a sudden surge in the adoption of RBIS across STEM departments. Through this work in progress we present preliminary data that we have collected to understand exactly why many faculty are now adopting RBIS. While this effort has led to the adoption of many RBIS, we focus on the adoption of personal response systems (clickers) and Peer Instruction. Preliminary data suggests that faculty adoption is being driven by community and collaborative instruction.

Keywords—change; research-based instructional strategies; communities of practice; clickers

I. INTRODUCTION

Our understanding about how to create change in engineering education primarily focuses on all the ways that change is difficult or slow. We now know that many change efforts rely on develop-disseminate models in which faculty develop new Research-Based Instructional Strategies (RBIS) and then disseminate them through publications and workshops [1-3]. These models have proven ineffective [4]. Faculty resist using RBIS due to clashes with their professional identities and challenges arising from a lack of time or access to training and development [5]. Even when faculty do attempt to implement RBIS, their fidelity of implementation is low [6].

In 2012, the College of Engineering created the Strategic Instructional Initiatives Program (SIIP) to transform and revitalize core engineering courses at the University of Illinois at Urbana-Champaign. During its three years of existence, the program has sparked the rapid spread of RBIS across the college and has created a thriving community of faculty invested in improving undergraduate instruction. For example, context-rich collaborative problem solving [7] (students working in teams to solve difficult, real-world engineering problems) has been integrated into 14 courses in five departments and has now been practiced by 27 faculty instructors, most of whom had not been using this RBIS before SIIP [8]. Further, SIIP has expanded beyond the confines of the College of Engineering and its model is being replicated across Science Technology Engineering Mathematics (STEM) departments in other colleges through NSF WIDER funding (DUE-1347722).

These efforts have rallied faculty around the simple message of “Teach like we do research.” Central to both SIIP and WIDER is a central model of change (See Figure 1). Somewhat counterintuitively, the primary goal of these efforts is not to stimulate the adoption of RBIS. Rather, the primary goal of these efforts is to create faculty communities of practice (CoPs) that provide an environment of shared vision and practice through which faculty seek to create collaborative, joint ownership of a target course or set of courses [2, 9]. Within these CoPs, faculty commit to an implement-evaluate development cycle for which the CoP must commit to collecting data about their innovations and using the data to inform iterative development. Finally, we expect that the adoption of RBIS will organically emerge without any particular mandates from the leadership team or administration [2]. Indeed, we have been seeing this organic emergence of RBIS adoption within our CoPs.

This work-in-progress paper provides our first steps toward understanding how and why these CoPs have supported such rapid adoption of RBIS in such a short time. In this paper, we present our preliminary efforts to track and explore the spread of personal response systems (clickers) and Peer Instruction [10, 11]. We begin by providing a brief background on the theory behind CoPs and Peer Instruction. We then describe our efforts to understand the spread of Peer Instruction and provide some lessons learned from preliminary data collection.

II. ORGANIZATIONAL CHANGE THEORY

Learning theories such as transformational learning theory [12, 13] and other situative frameworks such as Communities of Practice (CoPs) [9, 14] provide insights into why emergent, environmentally-focused change strategies can be effective. Decision-making during instruction and curriculum development is driven by faculty’s implicit epistemologies,
beliefs, and commitments [5, 15-17]. When these implicit value systems do not align with the implicit value systems of RBIS, faculty resist the initial adoption of those RBIS or will fail to persist in their use [17]. Transformational learning theory posits that implicit value systems can be changed only through mutual reflective engagement about communal practices such as teaching practices or curriculum design practices [12, 13]. CoPs provide a place for this mutual reflective engagement, inviting faculty to engage in continuously deeper levels with RBIS, from the periphery to the core [9].

Critically, faculty frequently have a central identity of self as expert in this classroom [5], an identity that can be at odds with student-centric RBIS. The mismatch in values can create a psychological “immune response” that seeks to guard existing identities and value systems and ward off invading identities [18, 19]. CoPs provide a safe environment for challenging this immune system, surrounding resistant faculty with respected colleagues, thus mitigating the perception of identity threat [9, 14]. Within CoPs, faculty engage in long-term situated learning, participating in community-valued practices [9, 14], creating a place for the assimilation of new values that align with RBIS.

After the peer discussion, the students again answer the question, and the instructor debriefs students’ responses [10, 11]. The conceptual questions play a key role in peer instruction, and should be written such that students get “a chance to explore important concepts, rather than testing cleverness or memory, and to expose common difficulties with the material” [11]. Students can provide answers to these conceptual questions through a show of hands, flashcards, or more recently, through the use of clickers [20].

While instructors have identified some challenges to using peer instruction, including the time needed to create appropriate conceptual questions, less time for lecturing, and some students’ discomfort with this method [21], students benefit greatly from this method. Peer instruction has been found to increase students’ conceptual learning and problem solving, and to decrease student attrition [20].

Interestingly, peer instruction benefits students regardless of whether students respond through clickers [20]. However, using clickers benefits instructors in a variety of ways: they “allow instructors to get precise real-time feedback,” they allow the instructor to archive student responses for future reference, and they move instructors to “shift their focus toward conceptual instruction” [20].

In their study on the fidelity of implementation of clickers, Borrego et al. identified four critical elements required for high fidelity of implementation of Peer Instruction: 1) Answer multiple-choice conceptual questions (MCQ) with distractors (incorrect responses) that reflect common student misconceptions, 2) Discuss a problem in pairs or groups, 3)
Use clickers or similar means to ‘vote’ on the correct answer of a MCQ, and 4) Provide answer(s) to a posed problem or question before the class can proceed [6]. It was observed that Peer Instruction has the lowest fidelity (11%) of implementation of all RBIS studied [6].

IV. CONSTRUCTION OF THE SURVEY

Project monitoring and evaluation revealed that many innovation CoPs created through SIIP and WIDER had begun using clickers in their classrooms. We also observed that some faculty used clickers in ways that aligned with principles of Peer Instruction, while others used alternate techniques. We decided to explore whether we could use a survey to study the spread of RBIS and their fidelity of implementation. While this particular survey focuses on clickers, we expect to use similar studies to examine other RBIS.

We constructed a survey to begin exploring two research questions.

1) How do faculty describe their own use of clickers?

2) Why did faculty decide to adopt clickers? Are the reasons for adoption of clickers different among SIIP and WIDER participants than other faculty?

The survey begins with five questions exploring when faculty first heard about clickers, how faculty first heard about clickers, when faculty started using clickers, what interactions or sources led faculty to adopt clickers, and what reasons (if any) delayed their initial adoption of clickers.

The second part of the survey explored the teaching practices that faculty used with clickers. A list of teaching practices was constructed both from the literature on Peer Instruction and from our observations of how faculty were using clickers in their classrooms. Faculty rated a list of practices (shown in Table I) on a Likert scale based on the frequency with which they used each of the teaching practices in conjunction with clickers. Three of the teaching practices (highlighted in Table I) were specifically focused on the critical components identified by Borrego et al. [6] and listed in the previous section. Faculty were also allowed to add any additional teaching practices they used that we did not list.

In addition to the Likert scale questions, faculty were asked to describe their ideal use of clickers and their perceptions of the benefits and tradeoffs of using clickers in their classrooms.

The final part of the survey was focused on tracking the spread of clickers. Faculty were asked to identify who or what persuaded them to use clickers, identify who they had persuaded to clickers, and identify others who they happened to know used clickers.

Sampling for this survey uses a snowball sampling method in which initial survey participants identify additional survey participants in their responses. This sampling method enables the sampling of targeted populations without a priori knowledge of where those populations reside. The Principle Investigators of the NSF WIDER project served as the initial seed samples for the survey.

TABLE I. FREQUENCY THAT FACULTY USE CLICKERS TO SUPPORT VARIOUS TEACHING PRACTICES. THE THREE HIGHLIGHTED ROWS CORRESPOND TO THE REQUIRED ELEMENTS OF PEER INSTRUCTION AS IDENTIFIED BY BORREGO ET AL. [6].

<table>
<thead>
<tr>
<th>Teaching Practice</th>
<th>Almost</th>
<th>Never</th>
<th>Occasionally</th>
<th>Usually</th>
<th>Always</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attendance</td>
<td>2</td>
<td>3</td>
<td>0</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Warm-up quiz w/ feedback</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Warm-up quiz w/out feedback</td>
<td>10</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>MCQ w/out peer discussion</td>
<td>6</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>MCQ w/ peer discussion</td>
<td>1</td>
<td>0</td>
<td>6</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Immediately reveal MCQ performance</td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>Instructor leads discussion after MCQ</td>
<td>3</td>
<td>3</td>
<td>5</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Adjust pace of instruction</td>
<td>2</td>
<td>4</td>
<td>5</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>End-of-class quiz w/ feedback</td>
<td>9</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>End-of-class quiz w/out feedback</td>
<td>12</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Collect early informal feedback</td>
<td>9</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

V. PRELIMINARY RESULTS

The survey has had 13 respondents at the time of publication. Due to the small sample size, we do not provide any statistical analysis of the data, but provide some initial tentative observations that we hope to explore further as we increase our sample size.

A. Why Did Faculty Adopt Clickers?

Figure 2 plots the year that faculty adopted clickers in their teaching practice against the year that faculty first heard about clickers. The earliest year reported for the use of clickers is 2005 – the year that i-clickers were invented on our campus. Not surprisingly, the first adopters were the inventors of i-clickers and their close colleagues. The only other early adopter is currently a principle investigator for the WIDER project. The majority of our sample (10 of 13) adopted clickers after the start of SIIP in 2012. A few of the senior faculty in the study heard about clickers shortly after the invention of i-clickers, but their adoption took place after being embedded into SIIP and WIDER CoPs (In Figure 2, see three data points of faculty who heard about clickers in 2006 and 2007 and adopted them after 2012).
Awareness and adoption of clickers was driven primarily by interactions with colleagues. Figure 3 shows that most respondents heard about clickers through conversations with colleagues or observation of another instructor. Noticeably, none of the adopters first learned about clickers from publications.

Faculty’s free responses to questions about why they adopted clickers similarly reflect the critical role of colleagues in their adoption as 10 of 12 responses indicate the role of colleagues in persuading them (the creator of i>clickers is omitted from these responses). Four of the respondents specifically mentioned their involvement with SIIP and WIDER CoPs.

Because of the preliminary nature of this data, exemplar quotations are provided to give readers a sense of faculty responses, but qualitative analysis of this data will occur after sampling has ceased.

“I had thought they were a great idea as soon as I heard about them; however, it was not until I took over a class in which the previous instructor had already used them that I decided to use them myself.”

“Existing course format required their use. Co-teaching with an experienced instructor (Prof. X) who was using them. He learnt about them from physics, I believe. I used them once with X in 2009, but it wasn't a great experience (bad format), so I didn't use them again until 2013 when I started using them as part of the SIIP project.”

B. How Are These Faculty Using Clickers?

Confirming the observations of the principle investigators, all of the listed teaching practices in Table 1 were chosen by the faculty. While each of the teaching practices are in use, the most common self-reported teaching practices align with the critical elements of Peer Instruction and tracking attendance. These results suggest that faculty connected with SIIP and WIDER may be using Peer Instruction with a higher fidelity than reported in previous studies, but these results are preliminary and firm conclusions should not be drawn from this data.

These results also reveal that faculty use clickers using a mixture of practices that align with the critical elements of the RBIS with practices that are not supported by the literature. Faculty’s free responses seem to corroborate these observations. Again, because of the preliminary nature of this data, exemplar quotations are provided to give readers a sense of faculty responses, but qualitative analysis of this data will occur later.

“I like iClicker questions best when they reveal common conceptual problems. By using them to reveal in real-time the misunderstandings that students have, the students become highly engaged to fix their faulty understanding of course concepts. I like to use mass-misunderstanding moments to open up discussions with their neighbors as an opportunity for students to truly consider the validity of their often-flawed reasoning. Then, by following up with a re-poll, I can open the floor for a student to explain what is hopefully the proper reasoning. This opportunity can be used to provide encouragement to students to confidently express their reasoning.”

“My best uses of iClickers is when I can sprinkle 3-4 questions throughout my lectures so that students stay focused and get immediate feedback on whether they understand the material. The other ‘best’ use is when I have a particularly tricky topic and can ‘wake up’ the students by showing them that a significant portion of the class is struggling with the concept.”

“To test on the same question first without allowing for discussion, and then again but after discussion”

VI. Future Work

This preliminary data suggests that faculty communities and social networks play an important role in faculty awareness and adoption of RBIS. Deeper analysis of the data will commence after the snowball sampling reaches saturation. These results suggest that we should conduct social network analysis to better understand the interconnections between faculty.

We expect to expand this survey to explore the spread of other RBIS and explore the generalizability of these findings.
REFERENCES


Abstract— In order to develop the engineers of the future, engineering departments need to embrace innovative, student-centered practices. The development and sustained growth of organizational improvement practices like those needed to improve engineering education depend upon an institutions’ or departments’ collective and individualized attention to human resources, leadership, knowledge development, revenue development and opportunities for continuous engagement. The literature in engineering education related to sustainability and curricular change indicates initial training and dissemination is necessary though not sufficient for change to take root, that all change agents need mentoring, collaboration opportunities, and venues for sharing their work, that innovative practices may vary across settings, and that a systemic effort needs continuous attention to remain robust. The paper provides CAHSI as an example of sustained innovation, and details the ways in which CAHSI was designed for sustained impact in engineering education across partnering Hispanic Serving Institutions. The paper highlights programmatic considerations and evaluation design, and describes how the results can inform leadership regarding progress and needs for sustaining change.

I. INTRODUCTION

In order to develop the engineers of the future, engineering departments need to embrace innovative, student-centered practices. Creating and maintaining pedagogical change in computer science and engineering departments is challenging, given short programmatic funding cycles and multiple demands on faculty time. This paper describes strategies employed by an alliance of eleven departments and external partners to improve educational outcomes for underrepresented students in computer science and engineering. The development of organizational capacity within this multi-institution initiative is important for engaging all members in the mission of the alliance and, over time, is crucial for contributing to sustainability of the alliance beyond the life of National Science Foundation funding. This paper situates the CAHSI model within the organizational change literature regarding how to motivate and sustain innovation in a department or institution. The paper provides CAHSI as an example of sustained innovation, and details the ways in which CAHSI was designed for sustained impact in engineering education across partnering Hispanic Serving Institutions. The paper highlights programmatic considerations and evaluation design, and describes how the results can inform leadership regarding progress and needs for sustaining change.

II. CAHSI

The Computing Alliance for Hispanic-Serving Institutions (CAHSI) is a Broadening Participation Alliance funded by the National Science Foundation. CAHSI is a cooperative effort among 11 core institutions that implements changes in computing pedagogy, research, and professional development opportunities in higher education collaborating to spread the promising practices developed at each institution. The goals of the alliance are to recruit, retain and advance Hispanics in computing. This paper documents elements of design and implementation within the organization that have supported sustainability and organizational change among member computing and engineering departments, and highlights ways in which the sustainability has been measured and monitored throughout the course of CAHSI’s 10 years.

Throughout its history, CAHSI has provided deep and broad support to students and faculty at all educational stages. The CAHSI model has consistently fostered deep student engagement throughout their undergraduate and graduate experiences. For instance, in the 2013-14 academic year alone, CAHSI departments provided:

- 24,840 hours of introductory computing content to 552 students, nearly 2/3 were Hispanic or other underrepresented minority students.
- 49,335 hours of undergraduate-led supplemental instruction through peer-led team learning (PLTL) to 1,905 students, nearly 60% were Hispanic or other underrepresented minority students.
- 10,305 hours of coursework using the Affinity Research Group (ARG) model to 255 students; 75% were Hispanic or other underrepresented minority students.
- 7,800 hours of out-of-class research experiences provided to 27 students; 71% were Hispanic or other underrepresented minority students.

These opportunities for substantive technical learning and deep engagement with the discipline build students’ self-efficacy, sense of mastery, and increase their aspirations to pursue graduate education and computing careers. During the last five years, 77% of all ARG undergraduate students reported that they were more likely to pursue graduate school because of their research experience; many of the remainder stated that they were already strongly committed to graduate study. CAHSI students also have higher aspirations than a national sample of computing students surveyed by the Computing Research Association. For example, 19% of
CAHSI students aspired to a doctoral degree, while only 12% of the national sample of students expressed that goal.

CAHSI has worked to sustain efforts and expand in manageable ways given shrinking governmental funding opportunities. This paper illustrates the ways in which CAHSI has made a concerted effort to leverage resources to support transformational educational practices. This paper is a case study of a long-standing collaborative organization. The data collected over 10 years of evaluation of the program describes some of the ways in which the design and implementation of the alliance across institutions has led to its longevity and impact. Building on organizational change literature, the evaluation of organizational capacity building efforts is described. Illustrative examples show how CAHSI has supported sustained curricular and co-curricular innovation in member institutions and beyond.

The research questions addressed in this paper are:

What factors of initiative design and emerging practice have supported sustainability for CAHSI?

What challenges remain in sustaining the CAHSI initiative?

III. ORGANIZATIONAL CHANGE LITERATURE

The development and sustained growth of organizational improvement practices like those needed to improve engineering education depend upon an institutions’ or departments’ collective and individualized attention to human resources, leadership, knowledge development, revenue development and opportunities for continuous engagement [1,2,3]. Johnson, Hays, Center and Daly [4] designate the need for infrastructure capacity building in change efforts. According to the authors, infrastructure capacity building objectives include the ability of the organization to:

“a) strengthen and maintain structures and formal linkages, b) strengthen, maintain, and cultivate leadership, c) increase or maintain resources to sustain innovation, d) build and maintain expertise to sustain the innovation.”

A. Innovation in Engineering

Studies of innovation in engineering education have looked at the most promising practices for sustaining innovation over time and for influencing other practitioners to incorporate inclusive, student centered approaches in their classrooms to promote change. Borrego and Henderson [5] described four types of change strategies employed in educational settings, and note the strategies that honor complexity, assume changes must occur within environments rather than only at the individual level, and that emergent rather than prescribed change might have the best chance at succeeding. Similarly, Sidiqui and Adams [6] called for approaches to educational change that moved beyond diffusion or propagation approaches in which curriculum as a bounded object is passed to multiple intended users. Instead, educational change efforts that address explicit assumptions about students, learning experiences, and goals prompting innovation might be more effective in creating lasting improvements in engineering education.

A National Science Foundation funded coalition of engineering education institutions reflected on their curricular change models as they evolved over time in the partnership, and concluded in its fourth generation change model that curricular change involved persuasion, developing tools and resources that would work for multiple audiences, and a need to provide structures that support curricular use and further development [7]. The literature in engineering education related to sustainability and curricular change reflects lessons learned in the CAHSI community—that initial training and dissemination is necessary though not sufficient for change to take root, that all change agents need mentoring, collaboration opportunities, and venues for sharing their work, that innovative practices may vary across settings, and that a systemic effort needs continuous attention to remain robust.

B. Transforming practice in HSIs

Hispanic serving institutions, defined by Title V of the United States federal government as institutions with 25% or greater full time enrolled students who identify as Hispanic/Latino, have particular demographic realities that shape the way postsecondary institutions address their needs. Hispanic serving institutions may have a higher than average number of community college transfer students, and may enroll a greater proportion of students with significant financial need, as well as students with school experiences at the K12 level that did not sufficiently prepare them for the rigors of engineering education [8,9] It is said that new educational initiatives can be expected to transfer to new sites based on the extent to which the educational sites are similar [10]. By partnering with other HSIs in transforming education in engineering, institutional agents can start from a place of common ground and develop shared and complementary expertise to transform education.

In a large scale study of transformative change among HSIs, Nunez, Hurtado, and Galdeano [11] document effective practices for engaging collaboration in Higher Education. In their research work with partnering HSIs primarily in the southern and western United States, they found four themes that related to institutional change and improved student outcomes in these strategic HSI partnerships: cross-institutional mentoring, changing mindsets, mutual encouragement and action, and the ‘ripple effect’. CAHSI was designed and implemented in ways that complement these 4 themes, and the themes serve to structure the results presented in this paper for research question 1.

IV. METHODS FOR EVALUATING ORGANIZATION CHANGE IN CAHSI

Evaluating organizational change across organizations involves a multilayered, mixed methods evaluation plan that documents student outcomes, programmatic reach, and based on needs of the funder, the impact of the partnership beyond the original funded organizations. To sustain the educational initiatives that serve students in alliance departments, the alliance must have the capacity to do the following: