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Successful Model for Professional Development: Creating and Sustaining Faculty Learning Communities

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BACKGROUND

Improving undergraduate science, technology, engineering, and mathematics (STEM) education is both an urgent national need and a long-term challenge (PCAST, 2012; AAU, 2011).The STEM fields are critical to generating new ideas, companies, and industry that drive our nation's competitiveness, and will become even more important in the future (Arum & Roksa, 2011). Nevertheless, there has been a steep decline in both the number and persistence of students in STEM majors. The decline in popularity of STEM programs is particularly marked among freshmen, who often leave the major soon after completing introductory science courses (Green, 1989; Seymour & Hewitt, 1997). Evidence is mounting that introductory coursework fails to inspire students and provide them with the foundational knowledge they need to persist and excel in STEM degree programs (Hurtado et al., 2010; Wood, 2009; Handelsman, 2004). Students leaving STEM majors express dissatisfaction with both the curriculum and the instruction, often perceiving that professors care more about research than student learning (Johnson, 1996; Marbach-Ad & Arviv-Elyashiv, 2005; Seymour, 1995; Seymour & Hewitt, 1997; Sorensen, 1999).

Faculty members clearly play a pivotal role in undergraduate STEM education reform. Through their enthusiasm and expertise, they shape the attitudes and aspirations of their students (Cole & Barber, 2003; Gaff & Lambert, 1966).

However, faculty members have essentially no formal preparation for their university teaching responsibilities (Tanner & Allen, 2006). While they are generally aware that prior knowledge plays an important role in the ability to acquire new concepts, they lack expertise in evaluating their students' prior knowledge and adjusting their teaching practices to frame their course as part of a learning progression (Marbach-Ad, Ribke & Gershoni, 2006; Duschl, Maeng & Sezen, 2011).

A recent Association of American Universities Report (AAU, 2011) urges a cultural change in how faculty members approach teaching. The traditional mode of undergraduate STEM instruction, characterized by long lectures where students take a passive role, emphasizes content coverage over conceptual mastery and leaves students deeply dissatisfied (Henderson, Beach & Finkelstein, 2011; Henderson & Dancy, 2008; Henderson et al., 2008; Seymour & Hewitt, 1997). Faculty members must move away from teaching a "sea of facts" and instead help students develop a meaningful conceptual understanding. The American Association for Advancement in Science report, *Vision and Change: A Call to* Action (AAAS, 2009) provides a consensus list of the major concepts that students in the biological sciences should understand deeply. Disciplinary societies such as the American Society for Microbiology (ASM) have voiced strong support for this approach and have developed curriculum recommendations that are grounded in a focused list of concepts aligned with those proposed in *Vision and Change* (Merkel, 2012). Using the process of scientific teaching (Handelsman et al., 2004), these curriculum guidelines can serve as the basis for designing courses that achieve specific learning outcomes using best practices for student learning. However, before meaningful change can be implemented in the classroom, it is imperative that we have a thorough understanding of the knowledge base of the incoming students, with an appreciation of their conceptual understanding about science and the world around them.

CONCEPT INVENTORIES AS A TOOL TO PROBE STUDENTS' CONCEPTUAL UNDERSTANDING

Well-designed concept inventories (CIs) are important tools for assessing the extent of student concept mastery. CIs generally consist of a series of multiple-choice questions that are informed by research into students' prior knowledge of a topic. Distractors for the multiple choice questions are developed with awareness of naive ideas, misconceptions, and faulty reasoning commonly shared by students (D'Avanzo, 2008; Fisher 2004). Misconceptions are ideas that differ from valid scientific explanations and also (1) tend to be shared by a significant proportion of the population; (2) cut across age, ability, gender, and cultural boundaries; (3) produce consistent error patterns (Osborne & Freyberg, 1985); and (4) are highly resistant to instruction (Fisher, 1983; Thijs & van den Berg, 1993). We are aware that some consider the term "misconception" to have a negative connotation and suggest instead using the terms "alternative conception" or "naïve conception," however for simplicity we hereafter use the term "misconception."

The first of the CIs to have widespread influence on undergraduate instruction was the Force Concept Inventory (FCI), which was developed in the '80s by the physics community to assess student understanding of fundamental Newtonian concepts (Hestenes, Wells & Swackhamer, 1992). The FCI has provided powerful evidence of the effectiveness of active-learning teaching methods over traditional, lecture-based methods (Crouch & Mazur, 2001; Hake, 1998; Mulford & Robinson, 2002). Following this lead, CIs have been developed across a range of STEM disciplines, including chemistry (Mulford & Robinson, 2002), geosciences and astronomy (Libarkin, 2008), engineering (Evans et al., 2003) and in biology and its subdisciplines (Smith & Marbach-Ad, 2010).

While CIs are widely used to assess student learning of targeted concepts, questions have been raised about how well multiple choice questions can measure deep learning (Smith & Tanner, 2010). This issue has been at the heart of a series of national, NSF-funded workshops on Conceptual Assessments in Biology (CAB)(DBI-0957363). The consensus of attendees at the most recent conference (CAB-III, 2011) was that there is value in CIs that call for students to provide open-ended responses in addition to selecting multiple-choice responses (Smith & Marbach-Ad, 2010). These types of instruments provide both quantitative and qualitative evidence of student learning, giving them great utility as faculty professional development tools. For example, CAB-III participants recognized the power of using CI data to create a state of cognitive dissonance in faculty members who declare that they have "covered" a concept in class, but learn from CI data that students poorly understand the concept.

OUR FACULTY LEARNING COMMUNITIES

Faculty Learning Communities (Cox, 2004) have emerged as a powerful mechanism for teaching reform and faculty professional development. Communities inspire faculty members to develop shared vision and expertise, and they provide motivation and support for those seeking to adopt new teaching practices. There are various types and models for faculty learning communities (see Chapter D2). We built our communities along the lines of Wenger's (1998) theory of community of practice where we focus on collaborative projects.

Here, we describe our two communities: the UMD Host Pathogen Interactions (HPI) FLC and the VT Microbiology (MICB) FLC. We will introduce the

UMD HPI FLC and then explain how the model for this community spurred the development of the Virginia Tech (VT) community, now an active and vibrant force for course transformation at VT.

The Host Pathogen Interactions Faculty Learning Community

In 2004, as part of a college-wide effort to reinvigorate the undergraduate biology curriculum, UMD faculty members with research expertise in the area of HPI formed a teaching community with the expressed purpose of creating a research-intensive undergraduate curriculum informed by best practices in teaching and learning. Collectively, these faculty members share responsibility for teaching nine undergraduate courses in the undergraduate microbiology curriculum, including a large introductory course in general microbiology. Prior to the establishment of the HPI FLC, the UMD faculty had operated as individuals, each of us teaching the way that we had been taught and rarely assessing our learning outcomes. With the increasing body of knowledge on how students learn science, we felt that it was time for a more collaborative and forward-thinking approach to teaching. The HPI teaching community was founded on shared research and teaching interests, and it mirrors the classic research group, where science faculty members gather regularly to share ideas, review data, and discuss current findings. We have detailed the history and initiatives of our FLC in a series of publications (Marbach-Ad et al., 2007, 2009, 2010).

Over the last ten years the number of members in the HPI FLC has varied due to new hires and retirement. The HPI Teaching Community now includes 14 members who represent all faculty ranks, including those with primarily teaching responsibilities (lecturers and instructors), as well as tenured/tenure-track faculty members who have done research in the area of host pathogen interactions. Gili Marbach-Ad, the director of the College Teaching and Learning Center (http://www.life.umd.edu/tlc/), is also an integral part of the group, providing expertise in science pedagogy and assessment. During our time as a community, we have developed thirteen HPI concepts, an assessment tool (HPI Concept Inventory) and transformed our courses according to current research in student learning in STEM courses (Cathcart et al., 2010; Injaian et al., 2011; Quimby et al., 2011; Senkevitch et al., 2011). Members of our group have become active in campus-wide and national STEM educational initiatives, including Vision and Change, and ASM curriculum reform.

The HPI Concept Inventory, Our FLC Tool

The HPI Concept Inventory was developed by the UMD HPI FLC as a way of measuring the success of various curricular initiatives (Marbach-Ad et al., 2010). We give the HPI CI as a pre-test and post-test to provide insight into student gains in understanding of HPI concepts within each of our courses and across the full program of nine courses. It consists of 18 multiple choice questions validated through an iterative process (Marbach-Ad et al., 2009, 2010). The multiple choice nature of the inventory allows for quantitative analyses with large samples of students. Students complete the CI online and provide their student ID to enable matching of pre-test and post-test scores, and allow for retrieval of demographic information (e.g., gender, major) from institutional records. After students answer each question, they are asked to provide an explanation for the answer they chose. These open-ended explanations provide a rich source of data for qualitative analysis. Since 2006, at UMD we have implemented the HPI CI in four to six courses each semester.

At the conclusion of every semester, our team meets for an extended work session to review the data, according to a specified protocol (Table 1).

Through this systematic analysis of our data, we have gained insights into our program and, as a result, have made substantial changes to our curriculum, including the development of a new introductory course for students majoring in microbiology (Marbach-Ad et al., 2010). Further, the data analysis has served to spur rich conversations among our team that have transformed how we think about teaching and student learning. The qualitative analysis review sessions in particular have encouraged serious conversations about the nature of student learning and the origins of common misconceptions. We consider the insights derived from this work as the most important motivator of our continued interest in curriculum reform. We have found that student explanations in response to the HPI CI questions hold information that is valuable in revealing how students understand or do not understand HPI concepts. Each

TABLE 1: Protocol for Analysis of HPI CI Student Pre and Post Responses

1. Data from the online CI are downloaded to Excel files.
2. Pre- and post-test means are calculated for each course and tabulated.
3. Student explanations for each question are sorted by distractor choice to facilitate qualitative analysis. Responses for each distractor are sorted alphabetically. Numbers of responses with and without explanations are recorded. For qualitative analysis, responses without explanations are deleted from the working spreadsheet.
4. FLC members meet to review and discuss student performance on the CI. Quantitative data (pre- and post-test means) are reviewed and discussed by the group as a whole. For qualitative analysis, faculty members work in pairs with laptop computers to read and discuss student responses to different subsets of CI questions. Each pair then reports their major findings to the entire group for additional discussion.
5. FLC members summarize findings defining common misconceptions that lead students to select particular distractors.

of us has used insights from HPI CI analysis to inform our teaching in various ways and support our development as informed educators.

Creation of the VT Microbiology Faculty Learning Community

We in the UMD HPI FLC hypothesized that similar deep analysis of student CI responses would motivate the formation and success of new FLCs. To explore this notion, we brainstormed to identify a group of faculty members who might be interested in forming a community motivated by discussion of CI data. We decided to approach colleagues in the Department of Biological Sciences at VT. We chose this route as VT, like UMD, is a research university, we have colleagues in the department with research areas similar to ours, and the department offers a full set of microbiology courses comparable to those at UMD. We found that as at UMD the faculty members at VT had a strong interest in teaching microbiology, however meaningful discussions about student learning and large-scale collaborative projects were not occurring.

We entered into a collaborative agreement with a set of VT faculty members. As a result, in Fall 2010 the VT Microbiology (MICB) FLC was formed with eight members. The VT MICB FLC agreed to use the HPI CI for pre- and post-assessment of student learning in a set of microbiology courses. The group would then meet to discuss the data as we have done (Table 1). To support the VT FLC the UMD group served as mentors in the review and the evaluation of CI data. To this point, the VT MICB FLC has employed the HPI CI as pre- and post-surveys in four courses (two of which are offered every spring and three every fall) since 2011. The discussion of data has supported the development of the learning community as we hypothesized.

THE BENEFIT OF CI DISCUSSION IN MOTIVATING SUCCESS OF A FACULTY LEARNING COMMUNITY

Above, we indicated the value UMD FLC members have placed on the discussion of CI data in motivating participation in the FLC, and in curricular and pedagogical transformation efforts. Similarly, VT faculty members have been engaged by these discussions. On a recent survey of our communities, in response to the question, "What impact has your participation in your FLC had on your teaching?" one VT faculty member reported that participation in the community encouraged him/her to "more formally link learning outcomes with class learning material and assessments." Another VT faculty member wrote, "I have learned more about misconceptions that my students have before they reach my classroom, and the unexpected ways that they think about information I present to them."

The success of the VT MICB FLC is further evidenced by significant curriculum transformation. The community transformed the set of microbiology courses in their department into a full microbiology major program using the HPI CI as the assessment tool. Also, the group is now participating in STEM education research conferences, and several members are involved in national STEM education initiatives. Further, the UMD and VT groups are now working on a collaborative project to define common misconceptions among students entering a general microbiology course. This work is ongoing and we plan to publish it in a microbiology education journal.

LESSONS LEARNED AND APPLICATION OF FINDINGS

The UMD and VT communities have similar and distinct attributes (Table 2). As both communities exist at research universities, we each are composed of significant numbers of tenure/tenure-track faculty members who have both research and teaching responsibilities. Each community meets a few times each semester, with the UMD group meeting more regularly over a longer span of time (10 years). Both communities have one of the community members serving as a facilitator who sets the agenda and prepares meeting materials and reports. Similar drivers motivate both sets of faculty members including a desire for excellence in teaching, concern for student learning of important principles in microbiology, the goal of offering a curriculum where learning in one course builds upon the prior course, and an interest in contributing to the scholarship of teaching and learning. The UMD FLC was formed with a stated main initiative to foster deep and research-oriented learning in HPI, whereas the VT group was motivated by the desire to create a new undergraduate major. For both communities, discussion of HPI CI data served to engage the members in the work of the community. For the UMD group, this began with the development of the tool. Reading student explanations for selection of distractors was necessitated to validate the HPI CI. We found the analysis so interesting and informative that we continued this work beyond the tool development stage, and analysis of CI data became a major part of the community work. VT adopted the UMD HPI CI and found the discussion of the data equally compelling.

The UMD FLC was developed in response to a call for proposals and has had funding from a HHMI grant to the College of Chemical and Life Sciences. The group also successfully competed for NSF funding that provided support for two years. With funding, we benefited from support for a statistician, external evaluator of our work, graduate students, money for travel, and the opportunity to provide lunch at meetings. The VT group has had only limited funding from their Office of Assessment and Evaluation to support a part-time graduate student for one summer. The UMD team has had a science educator as a long-standing member of the team who has introduced science education literature, assisted in curriculum design, pedagogy and assessment implementation, and supported the documentation and dissemination of the work.

Although the communities have distinctions, both have been successful on multiple levels: impacting courses, programs, and their institutions, as well as contributing to the national conversation of STEM reform.

TABLE 2: Attributes of the UMD HPI FLC and the VT MICB FLC

Institution	UMD	VT
Membership	14 members including tenure/tenure track (9) and instructors (5)	8 members including tenure/tenure track (6) and instructors (2)
Meetings	Three times/semester over lunch (1.5 hour) with half day working meetings between semesters	Two times/semester for 2 hours
Duration	2004–2015	2011–2015
Facilitator	One team member serves role as facilitator	One team member serves as facilitator
Motivation for participation	• Desire for excellence in teaching • Concern for student learning of field • Learning progression within program • Interest in producing publications on teaching and learning	• Desire for excellence in teaching • Concern for student learning of field • Learning progression within program • Interest in producing publications on teaching and learning
FLC Main Initiative	Foster deep and research oriented learning in host pathogen interactions	Assessment of new microbiology degree program expected by accreditation
Concept Inventory	Created the HPI CI	Adopted HPI CI
Funding	Funding from NSF and HHMI that allowed support for • Food at meetings—lunch • Science educator • External evaluator • Statistician • Graduate student support • Travel to meetings	Summer support for one part-time graduate student from VT Office of Assessment and Evaluation
Science Education Expertise	Science educator integral part of the team Facilitator participated in science education programs including ASM Biology Scholars	UMD Science Educator provided assistance. Facilitator participated in science education programs including ASM Biology Scholars

There are some crucial elements important for maintaining a vibrant FLC. Each FLC meeting must be planned in an efficient manner to maximize the potential of the teamwork. The role of the community facilitator is essential for pre-meeting preparation, directing the meetings, and documenting progress. Further, there must be a link to the greater science education community, either by members attending conferences and reading the literature, or through the help of a science educator who supports the team in this manner. Limited funding may hamper the success of an FLC if members cannot attend conferences and if there is not sufficient support for data collection and organization.

In conclusion, we believe that FLCs that participate in discussion of assessment data, like that collected from the implementation of a CI, provide the right mix of support and intellectual challenge to engage STEM faculty members and motivate them toward curriculum reform efforts. There is the myth that research faculty members do not value their teaching mission to the same extent as their research. This is evidenced in that it is common for research faculty members to engage in frequent conversations with colleagues about research, while it is rare for these faculty members to discuss their teaching, attend STEM education conferences, or complete a serious analysis of student learning in their courses. Yet we *are* interested in being excellent teachers. The discussion of the CI data with colleagues has provided us an entrée into science education research and terminology, and a community with which to act on our interests in science education.

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