

PROMOTING EVIDENCE-BASED CHANGE IN UNDERGRADUATE SCIENCE EDUCATION

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Ann E. Austin

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Ann E. Austin, Professor

Higher, Adult, and Lifelong Education

419A Erickson Hall

Michigan State University

East Lansing, MI 49924

Tel: 517-355-6757

aaustin@msu.edu

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Ann E. Austin

The literature on discipline-based education research has grown considerably in recent years, providing evidence of the effectiveness and impact of various educational practices. Despite the evidence, however, considerable concern focuses on the extent to which faculty members in STEM fields are integrating evidence-based practices into their teaching. The need for strong STEM teaching that results in significant learning gains remains. Yet, change in the practice of higher education faculty does not occur easily. This paper draws from the literature on organizational change to broaden understanding of which factors encourage faculty members to change their teaching practices and which serve as barriers that discourage faculty members' interest in using new pedagogical approaches.

Understanding how students learn and identifying strategies that are shown to be effective in promoting learning are important contributions to the puzzle of how to increase student learning outcomes. However, just as important is focusing on the teachers themselves. More learning is unlikely to occur without more attention to teachers and teaching.

Attention to teachers and teaching asks why faculty members either choose to use or adopt methods that research shows to be effective in producing student learning, or ignore evidence-based findings and continue with their regular practices. Faculty members are situated within contexts that exert considerable influence on how they think about their work, how they approach teaching, what they value, why they select particular teaching approaches, how they assess the relative value and impact of their teaching choices, and how they assess effort spent on teaching in relationship to effort on other activities. An approach to teaching reform that primarily emphasizes how students learn without equal attention to the teachers whose work it is to support and scaffold that learning assumes that faculty members will change the way they behave as teachers in response to data-based findings on effective methods. Observation of actual practice, however, challenges this assumption. Framing this concern, Fairweather (2008) has argued that "...research shows that acceptable research evidence of instructional effectiveness is a necessary but not sufficient condition for adoption of education reforms in STEM" (p. 11). The literature and research on organizational change can benefit those promoting innovation in STEM teaching and interested in encouraging faculty members to change their teaching practice toward more effective instructional strategies.

Drawing on the literature on organizational change, the paper uses a systems approach to identify and understand barriers to change in STEM teaching practice and to highlight factors and strategies that relate to individual faculty members' decisions to integrate evidence-based approaches into their teaching practice. The paper begins with an overview of the literature on organizational change and the usefulness of taking a systems approach to understanding change in teaching behavior. It presents a conceptual framework, supported by the organizational change literature, that highlights organizational "levels" relevant to change in teaching behavior and important organizational "levers" that can be used

to encourage such change. Second, the paper uses this framework to discuss systematically the barriers to change in teaching practice and possible strategies to encourage faculty members to use evidence-based methods in their teaching. The discussion is supported with both research and practical examples from relevant change efforts. Third, the paper offers specific recommendations to promote evidence-based change in undergraduate science education. Suggestions for needed research conclude the paper.

Taking a Systems Approach

Higher education institutions are complex organizations with multiple, loosely coupled, interconnected subsystems (Birnbaum, 1988; Bolman and Deal, 1991; Cohen and March, 1991; Weick, 1976). Individual faculty members bring their values, backgrounds, abilities, and aspirations into these organizations, and, within these complex contexts, they make decisions about how they will teach. Recognizing universities and colleges as complex institutions, researchers and change leaders (Austin, 1998; Eckel, Green, and Hill, 2001; Kezar, 2001; Lattuca & Stark, 2009; Senge, 1990) advocate taking a systems approach to understanding and promoting change in higher education.

A systems approach highlights several important aspects of organizations—in this case, higher education institutions—that are critical for understanding how and why change does or does not occur. First, higher education institutions are comprised of multiple contexts and cultures within which individual faculty members work and which influence the decisions they make about their teaching. These include the department, the college, the institution as a whole, and the external groups interested in and affecting universities and colleges and the faculty within them (e.g., accrediting associations, parents and employers, state and federal governments). These contexts can be conceptualized as “levels” of the system that influence faculty work in implicit and explicit ways.

Second, various elements or components within organizations can serve as useful levers for change—or conversely, can be barriers to change. Some of the key “levers” within higher education institutions include evaluation and reward systems, workload allocation, professional development opportunities, and the strategic use of leadership practices. How these levers are used (whether with intention or not) influences how faculty members do their work (including their teaching).

Third, a systems approach shows that multiple factors simultaneously influence faculty members’ choices about their teaching practice. While some factors may encourage use of new approaches to teaching, at the same time, other factors may discourage such innovative practice. Approaches to change that take a linear path, relying on one factor or intervention alone, are likely to be inadequate to result in the desired outcome. The multiple contexts within which faculty members work, and the influences and interactions of various system levers, need to be considered to understand change processes. Given that higher education institutions are complex organizations, change efforts are most effective when they use both a “top-down/bottom-up” approach, take into consideration the factors at work within the multiple contexts that affect faculty work, and strategically utilize multiple change levers.

Building on these themes from the organizational change literature, this paper provides a systems approach for examining the factors relevant to faculty members' decisions to engage in evidence-based change in undergraduate science education. The framework presented in Figure 1 highlights the following points: (1) individual faculty members bring values, backgrounds, abilities, and aspirations to their teaching that relate to the decisions they make; (2) teaching occurs within organizational contexts internal and external to the higher education organization that influence teaching-related decisions; and (3) several organizational levers are particularly relevant to faculty members' decisions about their teaching. This systems approach to change in teaching practices provides a framework for analyzing contextual factors and key levers in the system that affect faculty work and choices about their teaching behaviors.

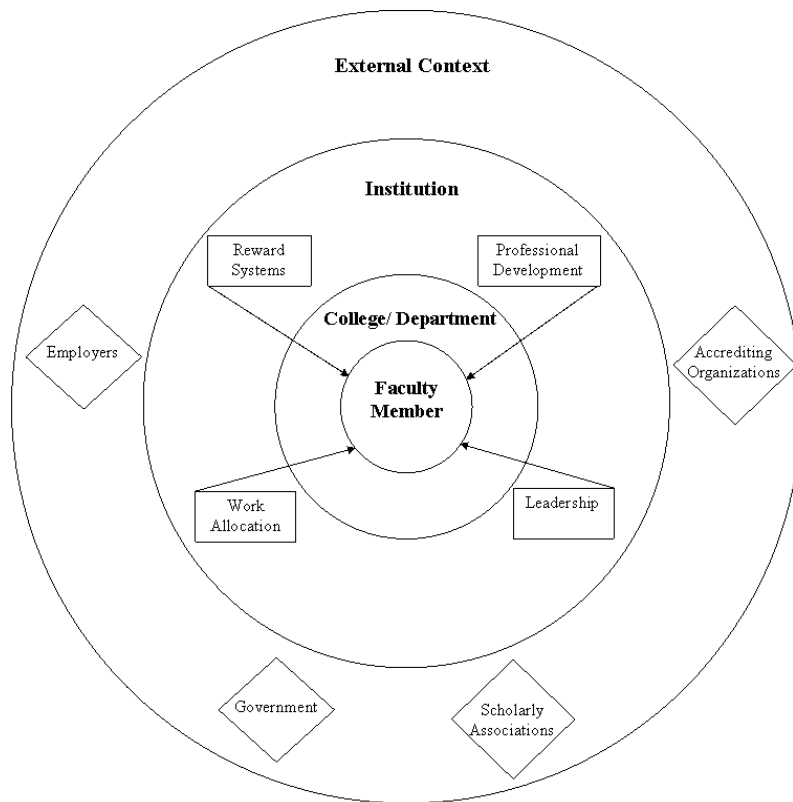


Figure 1. A systems approach to understanding faculty members' teaching -related decisions.

Relevant Individual Characteristics

Examining the individual variables that affect faculty members' approaches to their work is an important part of understanding the way they teach. Each faculty member is unique in bringing particular experiences, expectations, interests, and values to the academic appointment. Prior educational experience, socialization and preparation for faculty work, discipline, career stage, appointment type, and motivation are key variables that influence faculty members' decisions and actions.

Prior Experience

Research concerning early career faculty members and doctoral students shows that they often are eager to share their passion for their disciplines and fields with novice learners (Austin, 2002, 2006, 2007; Rice, Sorcinelli, & Austin, 2000). At the same time, many new teachers in higher education confess that they are not very sure how to go about teaching and translating their knowledge and enthusiasm for their fields to others. Their typical approach, as they explain in interviews, is to model their teaching after their memories of their undergraduate and graduate experiences—either emulating what they remember as effective teaching approaches or trying to avoid doing what they found less helpful. New teachers often assume teaching is improved by adding more content knowledge into lectures; this approach often is counter-productive to research that shows that good teaching provides students with time to interact and engage actively with the concepts and information to be learned (Chickering & Gamson, 1987).

Doctoral Socialization

Doctoral education provides a major period of socialization in which prospective faculty members explore and learn about the work they will do, what is valued and rewarded in academe, and what kinds of identities they wish to develop as faculty members, scholars, and teachers (Austin, 2002, 2003, 2010a; Austin & McDaniels, 2006; Wulff, Austin, Nyquist, & Sprague, 2004). Research indicates, however, that many students receive no formal preparation for teaching during their graduate experience (Austin, 2002; Golde & Dore, 2001), although more programmatic attention appears to be emerging over recent years (Austin, Connolly, & Colbeck, 2008; Austin et al., 2009; Wulff & Austin, 2004). Their faculty members and advisors have a major influence on the nature of socialization they experience, and, for students in the sciences, the faculty advisor is likely also to be leading a laboratory in which the doctoral student is working. Doctoral education is an apprenticeship experience in which doctoral students and post-doctoral scholars watch carefully the activities and priorities of the faculty members with whom they work and who advise them (Austin, 2002; 2009; Wulff & Austin, 2004). Values and norms are conveyed and embedded in the thinking and behavior of the next generation of faculty in many moments of daily observation and interchange. Doctoral students often recognize and can articulate, when asked, the mixed signals they typically receive within this socialization process concerning the value of teaching as part of faculty work and the trade-offs of putting time into good teaching practice. For example, doctoral students notice that awards bestowed for teaching excellence often are valued far less strongly than recognition for research excellence. Many also report receiving

guidance from faculty advisors that they should avoid spending too much time on responsibilities they may have as teaching assistants and, in some cases, receiving explicit instructions to avoid spending time on teaching-related professional development experiences, based on concern that such activities would draw them away from their research work (Austin, 2002). For faculty members who employ doctoral students and post-doctoral scholars in their labs, time devoted by such doctoral students and post-docs to teaching improvement is sometimes viewed as directly undermining research productivity on the faculty members' funded projects.

Various institutional and national efforts recognize both the opportunity offered by graduate school to shift the socialization of prospective faculty toward greater commitment to good teaching as part of their career aspirations and the challenges to this goal embedded in the structure and norms that have developed within the doctoral experience (e.g., where students are both learners and employees, and where norms about the relative value of research versus teaching are long-established) (Wulff & Austin, 2004, 2010; Austin et al., 2009). Some graduate schools make a simple but strategic choice to offer professional development experiences to doctoral students and post-docs in the evening or on weekends, so advisors and research supervisors do not notice their absence from laboratories during daily working hours.

On the national level, the Center for the Integration of Research, Teaching, and Learning (CIRTL), supported by the National Science Foundation, has created a collaborative alliance among six universities to develop institution-level as well as national-level professional development opportunities for doctoral students and post-docs (Austin et al., 2008; Austin et al., 2009). CIRTL emphasizes three "pillars" as its signature themes: preparing STEM future faculty to bring their skills of inquiry as scholars to their teaching ("Teaching-as-Research"); using "Learning Communities" at the institutional and national levels as the context to support professional development, thus providing a counter-balance to messages that devalue the importance of preparation for the teaching role; and preparing future faculty to recognize and develop the skills to use diversity within their classes and research environments as a basis for enhanced excellence and learning ("Learning-through-Diversity"). Research results show that participants in CIRTL professional development programs are developing a greater sense of the value of teaching as part of their careers, approaches to analyzing teaching problems, skills to encourage student learning, and appreciation of communities that support their commitment to effective teaching as an important part of into their careers (Austin et al., 2008).

Research also suggests that a substantial number of doctoral students in recent years wish to find career opportunities in teaching-oriented higher education institutions (Austin, 2002). Some are excited about working with undergraduates and enjoy teaching; others express skepticism about the pressures, competing demands, and lack of work/life balance which they say they observe in the lives of their faculty and advisors. Programs such as CIRTL offer doctoral students opportunities to consider a range of future careers, including some that may be different from the research university careers modeled by their advisors. Graduate schools at some universities also are offering workshops so doctoral students can become familiar with the range of higher education institutions in which they might work, including liberal arts colleges, community colleges, and teaching-oriented regional universities. Since research has

shown that students typically are unfamiliar with these options for teaching-oriented environments (Austin, 2002), such workshops serve to support their interest in developing as teachers and provide information relevant to career choices.

Discipline

In addition to prior educational experiences and doctoral socialization, discipline, career stage, and appointment type are three other factors relevant to understanding individual faculty members' perspectives on teaching. Disciplines have distinct cultures, including values and criteria about what constitutes excellent work and norms for the behavior of members of the field (Austin, 1994, 1996; Becher, 1987). In recent years, some disciplines have encouraged considerable attention to teaching improvement and welcome colleagues who engage in Discipline-Based Education Research (DBER); others may provide a less hospitable environment for this kind of work.

Career Stage

Faculty members are likely to face different pressures and expectations, and have varying perspectives about their work, at different points in their careers (Austin, Sorcinelli, & McDaniels, 2007; Austin, 2010c; Neumann, 2009). New faculty members are trying to figure out institutional expectations and make the transition in their sense of identity from graduate student or post-doc to faculty member. The literature is consistent in showing that the most common concerns of faculty members at this career stage are how to interpret mixed messages about where to put their time (which includes uncertainties about allocating time to research, teaching, advising, committee work, service, and other duties), figuring out the tenure and promotion process, establishing a sense of community, and negotiating work/life balance (Austin, Sorcinelli, & McDaniels, 2007; Rice, Sorcinelli, & Austin, 2000). Recent research has focused on the mid-career for academics, a period loosely defined from the point of tenure to the period within a decade of retirement. Mid-career faculty, particularly those who have recently achieved tenure, report their work is characterized by particularly heavy workloads, involving teaching, administrative responsibilities, and efforts to maintaining their research productivity (Baldwin, DeZure, Shawn & Moretto, 2008; Baldwin, Lunceford, & VanderLinden, 2005). Based on her intensive qualitative research, Neumann (2009) also reported that the nature of faculty work shifts as faculty move past the tenure decision, with pre-tenure faculty organizing their work more closely around institutional missions and post-tenure faculty seeking to expand their learning as they assume new roles.

Appointment Type

Across American higher education, a shift in balance is occurring from tenure-track appointments toward non-tenure-track, fixed-term, contingent, and part-time positions (Baldwin & Chronister, 2001; Gappa, Austin, & Trice, 2007; Schuster & Finkelstein, 2006). The impact of this shift on faculty attention to teaching is not yet clear. On one hand, adjunct and part-time faculty members do a great deal of teaching (Baldwin & Chronister, 2001; Finkelstein, Seal, & Schuster, 1998), and, in some fields, have been among those most interested in teaching innovation. For those non-tenure-track, fixed-term, or adjunct faculty members whose appointments do not include meeting research expectations, time

spent on teaching does not compete with time on research. However, if departments increase the proportion of fixed-term and part-time faculty members in relation to permanent, tenure-stream faculty, as is occurring at many institutions (Gappa, Austin, & Trice, 2007), they may marginalize efforts to improve teaching. For example, in STEM departments, fixed-term faculty members are often assigned large first- or second-year courses; in such a departmental context, permanent faculty may perceive that these fixed-term faculty members are “the ones who are supposed to worry about teaching.”

Faculty Motivation

Blackburn and Lawrence (1995) thoroughly examined research on faculty motivation, concluding that faculty members' interests, sense of self-efficacy (expectation and likelihood of being successful), and sense of rewards are the interacting variables that affect their motivation. Thus, efforts to encourage them to integrate evidence-based change into their teaching would need to consider whether they know what to do to use new pedagogies effectively, whether they think the effort would result in success, and whether they perceive the reward for such effort to be sufficiently valuable to them. Additionally, as discussed, faculty members' prior educational experiences, doctoral socialization experiences, disciplinary membership, career stage, and appointment type have considerable impact on their interest in teaching and their self-evaluation of their ability to do it effectively. Thus, efforts to encourage faculty members to change their teaching practice should take into account the ways in which individual faculty members differ.

Contexts affecting Faculty Practice

While faculty members bring their unique experiences and perspectives to their work, the contexts in which they are situated also influence them. For faculty members, the most salient contexts are the institution in which they are employed and the department and college where they hold an appointment, as well as the external organizations that influence, either directly or indirectly, their work.

Institutions

A distinctive characteristic of American higher education is the array of institutional types, including those offering the associate's degree, the bachelor's degree, the master's degree, and the doctorate, as well as tribal colleges and special focus institutions (Carnegie Foundation for the Advancement of Teaching, 2007). Teaching, research, and service are considered the common elements of faculty work, but the relative focus that faculty members are expected to allocate to each of these missions varies depending on the type of institution (Gappa, Austin, & Rice, 2007). While a faculty member in a community college spends the great majority of his or her time on teaching, some faculty members in research-oriented, doctoral-granting, institutions may teach only one or two courses a year, if they are “bought out” to allocate their time to funded research. Within the institutions between these poles, including liberal arts colleges and “comprehensive” master's institutions, the expectations for work allocation vary considerably depending on institutional history, aspirations, and resources. In some of the selective liberal arts colleges and regional comprehensive institutions, aspirations for greater

institutional prestige lead to mounting pressures for faculty members to increase their research productivity. In many higher education institutions today, facing constraints on revenue, rising costs, and, in public institutions, declining state allocations, faculty members face considerable pressure to engage in entrepreneurial activity to bring in more revenue to the institution (Gappa, Austin, & Trice, 2007). How much time and inclination faculty members feel for teaching reform relates to their understanding of institutional missions and priorities, as well as to the other pressures they perceive from their institution pertaining to where to put their time.

Department Context

While institutional type determines the overall context in which faculty members consider the importance of teaching, departments are the immediate context influencing how they allocate and prioritize their work time (Austin, 1994, 1996). The initial point of evaluation of faculty members for reappointment and tenure and promotion occurs within departments, work assignments are allocated at this level, and interactions among the faculty members contribute to the overall culture and tone. Specific departmental characteristics relevant to faculty members' decisions about teaching include the priorities set by a department chair, the overall focus of the department's culture on teaching, the expectations set for students, and the structure of the curriculum, particularly in relationship to course sequencing and the relationship of specific courses to others in the curriculum.

Department chairs sit in a "linking pin" role, connecting institutional priorities and faculty work, translating messages from senior institutional leaders, and interpreting questions, issues, and concerns expressed by faculty members (Bensimon & Ward, 2000; Chu, 2006; Leaming, 1998). The ways in which department chairs convey institutional interest in teaching excellence as compared to institutional pressure for faculty produce more research revenue or to engage more directly with external audiences, perhaps in revenue-generating activities, influence how faculty members understand what they are asked to do and what they privilege in their own work. Research shows that early career faculty members especially seek signals from chairs about institutional priorities in order to make choices among competing expectations (Rice, Sorcinelli, & Austin, 2000).

The department also is the place where curricular decisions are made. Within department curriculum committees, faculty members make decisions about requirements for degree completion, sequencing of courses, and the relationship of courses to each other in terms of what is taught. If the curriculum assigns certain content to particular courses, faculty members may find that they must be more concerned about content "coverage" than depth of learning. If attention within the department does not provide opportunities for faculty to discuss the intended learning outcomes of the overall curriculum and of individual courses, or to examine difficult concepts and components within the curriculum and where those concepts are best placed for optimal learning, individual faculty members are left on their own to grapple with whatever problems related to curricular structure emerge within the courses they teach. Some courses, either by design or tradition, may be informally viewed as the place to "weed out" students who are not sufficiently serious or academically strong to continue in the department. In such courses, faculty members may conclude that there is little reason to spend time on developing teaching

approaches whose goal is to optimize the learning of the greatest number of students possible. This array of curricular issues that occurs at the department level has many implications for the decisions faculty members make about their teaching practice, such as whether to adopt new pedagogies.

Class size and physical location assigned for a course are other relevant issues, often determined at the department or college level. Perceptions about the time required to use some strategies may deter adoption of these teaching approaches by busy faculty members, especially if they have little or no help from teaching assistants (TAs). Some class settings are less conducive to teaching strategies that encourage student interaction; desks and chairs that cannot move, for example, make organizing small group work more challenging. Research on innovation in physics teaching indicates that such issues as class size and location serve as barriers to faculty adoption of innovative teaching approaches (Henderson & Dancy, 2007).

Another aspect of the departmental context pertains to decisions about who teaches what courses. These decisions are made by chairs, program coordinators, or curriculum committee leaders. At some institutions and within some departments, teaching assistants are regularly assigned to teach lower-level introductory courses. If the goal of a course is to ensure optimal student learning, then careful thought about the expertise and preparation of the individual doing the teaching is necessary. Anecdotal observation reveals a number of examples of situations where teaching assistants are assigned just shortly before courses begin, precluding time for preparation and coordination with other teachers. Further concerns are whether TAs have teaching training, and, in instances where international students are serving as TAs, whether their English is at an appropriate level.

Several studies of reform in engineering education emphasize that such curricular issues as course sequencing and allocation of workload (Fairweather, 2008; Fisher, Fairweather, & Amey, 2003) can be important barriers to curriculum reform. Improving learning in undergraduate STEM courses may depend as much on attention to these kinds of factors related to departmental culture, curriculum content, sequencing, and assignment of teachers as it does on research on the impact of various teaching methods.

External Contexts

The environment external to higher education institutions constitutes another context affecting faculty work. Lattuca and Stark (2009) have developed a research-based model showing that external factors, as well as forces internal to higher education institutions, impact the "curriculum," which they define to include not only content but decisions about teaching practices. Examples of stakeholders within the external environment include employers, who have expectations for the qualifications of new graduates entering the workforce, and government agencies, which sometimes announce guidelines for reform or highlight concerns about educational practices. Accrediting agencies also can influence educational processes within higher education. For example, ABET, the accrediting agency of engineering programs in the U.S., adopted standards called EC2000 in 1996 that called for greater emphasis on learning outcomes rather than the more traditional focus on educational inputs. Evaluation research to assess

the impact of the EC2000 accreditation criteria showed that “changes in engineering program curricula, teaching methods, faculty practices, and students experiences inside and outside the classroom”-- changes aligned with the new criteria-- have contributed to improved student learning (Lattuca, Terenzini, & Volkwein, 2006, p. 13).

Additionally, scholarly associations provide another context within which faculty members work. Some associations include workshops on evidence-based research on teaching at their meetings and provide professional development experiences for their members, including aspiring faculty members. Thus, efforts to promote change in education practice should not exclude attention to the influence of the external context.

Levers Impacting Faculty Members' Teaching Practice

From a systems perspective, several components within the organizational environment can operate as barriers to change or can serve as “levers” to promote change in faculty behaviors. This section highlights four levers that have direct relevance to faculty decisions about teaching.

Reward Systems

The reward system serves as a key lever relating to faculty members' decisions about their teaching. Higher education institutions are sending strong messages about the relative value of time spent on research versus time spent on teaching. Specifically, several studies show that higher education institutions value research more than teaching (Fairweather, 1996, 2008; Massey, Wilger, & Colbeck, 1994). For example, based on their extensive quantitative study, Schuster & Finkelstein (2006) concluded that, across four-year not-for-profit institutions, faculty reported increasing pressure to do research. Braxton, Lucky, & Holland's (2002) research showed that, across four-year institutions, publishing research is most important in faculty tenure and promotion decisions. Examining determinants of salary, Fairweather (2005) concluded that, as faculty time in class increases, salary level decreases. He also found that across all four-year institutions, including liberal arts colleges, scholarly productivity and publications are the strongest predictor of faculty pay. In salary decisions, teaching and research are “pitted” against each other.

How do faculty respond to these institutional signals and messages? The consensus among the researchers who have looked closely at this question is that teaching becomes a less preferred option. Massy and Zemsky (1994) concluded that, in order to increase time for research, faculty members choose to simply “suffice” in their teaching responsibilities. Leslie (2002) concluded from his research that, due to the reward system, faculty will choose to spend time doing research even when they are strongly committed to teaching. Fairweather (2005, 2008) explained that the involvement of faculty members in change efforts related to their teaching is diminished when they perceive that such efforts give them less time to do research, which is more valued by the institution. Citing the collective findings of key researchers (Fairweather, 2005; Leslie, 2002; Massy & Zemsky, 1994), Fairweather's recent paper (2008) for the National Academies National Research Council Board of Science Education argued persuasively that faculty who are not yet choosing to use newer pedagogies will be more influenced

toward engaging in change by rewards and work allocation than by data-based evidence about the new pedagogies. At minimum, if faculty members are to consider investing time in developing new pedagogies, they must not feel that such time will be a negative factor in salary and advancement considerations.

Work Allocation

Work allocation also can be a barrier to new teaching behaviors or used as a lever to encourage change. As discussed, reward systems affect faculty behavior. Additionally, time issues affect faculty members' decisions about their work. Studying reform in engineering, Fisher, Zeligman, & Fairweather (2003) found that teaching innovations shown through research to be effective did not spread widely because faculty members did not want to spend more time on teaching than needed for traditional lecture approaches. Studying resistance to reform among faculty in physics, Henderson & Dancy (2007) reported that 53% of their respondents indicated that an important barrier to changing practice is the time needed to learn and implement new teaching strategies. Implications are that new teaching strategies must be easy to use (Fairweather, 2008), that faculty members must see ways to adapt new strategies (relatively easily) to their own teaching situations (Henderson & Dancy, 2007; Dancy & Henderson, 2010), and that faculty members have enough time to learn and implement the strategies.

The research pertaining to time and faculty interest in teaching innovation has implications for workload allocation decisions. Teaching strategies that are perceived as needing considerable time to learn and to fit into a course seem unlikely to attract many faculty members willing to try them. Institutional leaders wishing to encourage reform in teaching should consider whether workload assignments can accommodate time and space for faculty members to learn about and experiment with new pedagogies. If time deters faculty members from experimenting in their teaching, then one lever for change is to build such time into workload assignments, coupled with expectations for accountability for how the protected time is spent.

Professional Development

The research on faculty motivation emphasizes the interaction among rewards, interest, and sense of self-efficacy (Blackburn & Lawrence, 1995). Even if faculty members perceive that an activity will be rewarded, they must also feel interested in the activity and have a sense that their efforts are likely to be successful. Professional development relates to faculty interest and sense of self-efficacy. In a recent survey, faculty development professionals in North America assessed that, over the next several years, faculty members are most likely to need support in the following areas: (1) balancing multiple roles and learning new roles; (2) supporting student learning through student-centered teaching, assessment of student outcomes, and teaching underprepared students; and (3) integrating technology strategically into teaching and learning environments (Sorcinelli, Austin, Eddy, & Beach, 2006). Recognizing support for effective teaching as an institutional strategic priority, many universities offer faculty development programs designed to meet faculty needs at different career stages (Gappa, Austin, & Trice, 2007). However, a challenge for faculty developers is to find ways to attract busy faculty who face many

competing expectations and pressures. Those already using innovative pedagogies often seem the most eager to participate, while those less involved in teaching reform are reluctant. Faculty developers share some common observations: 1) professional development is more attractive when it is presented as a prestigious and growth-oriented opportunity, rather than a remedial situation; 2) faculty members have different needs and interests in regard to professional development opportunities at different stages of the career; 3) offering various ways to access professional development opportunities, including through technology, appeals to the varying circumstances and preferences of an increasingly diverse faculty population (Gappa, Austin, & Trice, 2007; Sorcinelli, Austin, Eddy, & Beach, 2006).

Some of the most promising and effective professional development opportunities, particularly among STEM faculty as well as among faculty members and doctoral students in other fields, involve learning communities. With roots in theories of situated learning and cognitive apprenticeship (Austin, 2009; Collins, Brown, & Holum, 1991; Lave & Wenger, 1991), learning communities provide opportunities for faculty members to interact with others as they explore new assumptions and try out new approaches to teaching and learning. Learning communities enable faculty members –or doctoral students aspiring to the faculty role—to explore and experiment with new approaches to teaching in an environment that simultaneously provides challenge and support. In institutional contexts that privilege research over teaching, such communities provide support for individual faculty members who otherwise might feel alone in their departments with regard to their interest in teaching innovation. In their study of the impact of EC2000, a major engineering change endeavor, Lattuca, Terenzini, & Volkwein (2006) reported that opportunities for professional development played a role in creating faculty cultures that contributed to greater student learning.

Across the nation, several initiatives provide interesting examples of different kinds of learning communities that promote teaching improvement. At the department level, Coppola (2007) has established communities in which chemistry doctoral students integrate research and teaching; these communities are producing doctoral graduates with commitment to teaching excellence coupled with knowledge of pedagogical innovation. At the institution level, Cox and his colleagues at Miami University in Ohio (Cox, 2001), have created cross-departmental learning communities of faculty members that facilitate structured conversations about topics pertaining to their teaching practice. Also at the institution level, the University of Massachusetts Amherst has been supported by the Mellon Foundation to develop a cutting-edge approach to mentoring that supports new faculty members through a process of “mutual mentoring.” This approach offers opportunities for early career faculty to identify a group of mentors who together provide a community of support (<http://www.umass.edu/ofd/mentoring/pguide.html>).

The Center for the Integration of Research, Teaching, and Learning (CIRTL), funded by the National Science Foundation, situates professional development within learning communities both at the institutional level and across a network of institutions. CIRTL provides professional development opportunities to prepare doctoral students and post-doctoral scholars for careers as effective teachers as well as researchers. The results of research on the impact of the CIRTL-related professional development programs indicate that participants gain knowledge and skills concerning teaching

(including knowledge about curriculum development and lesson design, strategies for engaging students, teaching methodologies, and assessment of learning). Participants also report gaining a greater understanding of how to study their teaching and their students' learning and indicate greater awareness of the importance of recognizing and building on diversity within the classroom. Furthermore, participants often indicate that they feel better prepared for undergraduate teaching and feel a greater sense of self-efficacy regarding teaching, and that they value opportunities to interact with others with similar interests regarding teaching (Austin et al., 2008).

Leadership

The strategic use of institutional leadership practices constitutes another lever that can encourage faculty members to use innovative pedagogies. Leaders at each level of the institution are important in creating a culture that encourages, supports, and rewards teaching innovations that support student learning. For example, provosts play an important role in articulating institutional commitment to student learning and teaching excellence. They can provide guidelines for tenure and promotion reviews, emphasizing the importance of commitment to teaching excellence as part of the review criteria and the expectations for success. Deans and department chairs strongly influence what is valued within their units and can provide specific support for professional development opportunities coupled with incentives for faculty members to participate. Overall, institutional leaders can affect tenure and promotion processes and criteria, allocate resources, and provide symbolic support for the importance of excellent teaching within institutional missions.

Results emerging from studies of two major funded change projects highlight the importance of support from institutional leaders as levers for change. The first study focuses on institutions that have participated in the National Science Foundation ADVANCE Program, whose purpose is to encourage institutional change that enhances the recruitment, retention, and success of women faculty and scholars in STEM fields. Early findings suggest that the involvement of senior institutional leaders in explaining the importance of institutional attention to increasing the number of women STEM colleagues is an important factor in advancing change goals (Austin, Laursen, Martinez, & Soto, 2010). Second, emerging evaluation results from a study of the establishment of CIRTl activities at the institutional level (Austin, 2011; Micomonaco & Austin, 2010) also highlight the importance of institutional leaders in change efforts. Furthermore, elements that foster the creation of innovative and effective professional development programs include: (1) the presence of an institutional leader who serves as a champion, is committed to the overall CIRTl goals, and has sufficient institutional seniority to allocate institutional resources and time; (2) an institutional team that meets regularly, works together effectively, and includes STEM faculty as well as other institutional leaders; (3) a clear institutional vision for the goals to be accomplished; and (4) regular communication to key individuals and groups across campus.

An increasing number of higher education institutions are providing leadership development for deans and department chairs (Sorcinelli, Austin, Eddy, & Beach, 2006). These programs include workshops designed to help institutional leaders develop specific skills as well as year-long programs in which

prospective or current leaders deepen their understanding of institutional missions, their roles in framing and supporting those missions, and specific strategies to use leadership skills as a strategic lever for change. Institutional leaders skilled in organizational change processes and committed to teaching excellence can use their positions as levers to encourage faculty attention to new teaching practices.

Recommendations for Promoting Evidence-Based Change in STEM Undergraduate Education

This analysis of a systems approach to understanding factors related to STEM faculty members' decisions to engage in evidence-based changes in their teaching practices leads to several recommendations:

- Efforts to improve learning should build on the research concerning the factors that relate to faculty members' behaviors as well as the research on the effectiveness of specific teaching strategies.
 - Improving student learning requires: (a) knowledge about how students learn; (b) knowledge of effective teaching strategies; (c) faculty members who understand processes of learning and what strategies are effective under what conditions; and d) faculty decisions to implement such knowledge of learning processes and teaching strategies into their own practice. Each part of this constellation of ingredients is necessary to encourage student learning. Research findings on effective strategies do not lead to enhanced learning if teachers do not know, are not willing, or feel disadvantaged by using those strategies. Thus, efforts to improve student learning need to consider the research pertaining to faculty motivation and the factors that affect faculty behaviors.
- Efforts to encourage faculty members to change their teaching practices should take into account the individual characteristics that relate to faculty perspectives on and decisions about teaching. Faculty members will vary in their knowledge of and interest in integrating evidence-based methods into their teaching. Thus, efforts to encourage change in faculty teaching behavior need to be designed in ways that account for these individual differences.
 - Faculty members are each unique, with perspectives on teaching relating to prior experiences, socialization as doctoral students, disciplinary home, career stage, and appointment type. Encouragement to engage in new teaching practices must respond to individual circumstances. A new faculty member, for example, may need guidance to learn basic information about the university and its resources, before she is sufficiently confident to try teaching approaches that are new to her. Someone who has participated in a professional development program such as CIRTLL may need assurance that the ideas and expertise he brings will be valued and rewarded within the higher education institution where he is hired. A busy senior faculty member leading several

research grants may only be interested in integrating new strategies into his teaching if he has support from teaching assistants who know how to implement the new approach. In other words, faculty members need and respond to different kinds of support.

- Successful change efforts take a systems approach in both recognizing relevant factors within the multiple contexts in which faculty work and key strategic levers that promote faculty involvement in teaching reform. Several strategic approaches seem most promising in encouraging faculty members to use evidence-based teaching methods:
 - Professional Development
 - § In order for faculty development to serve as an effective lever for change, institutions need to encourage more than the “usual crowd” to participate. Department chairs and deans need to make clear that participating in faculty development focused on teaching improvement is valued by the institution. Those designing professional development activities must ensure that every program makes effective use of time and results in substantial and positive outcomes for participants. Furthermore, to cater to diverse faculty members, an effective menu of opportunities should include various formats, including technology-based resources and seminars as well as traditional in-person workshops.
 - § An effective strategy to encourage innovation and experimentation in teaching involves building networks and learning communities in which faculty members can support each others’ learning and teaching experimentation. Institutional leaders can convey the message that participation in such professional learning communities is encouraged and should ensure that attractive rewards are linked with faculty involvement.
 - § Many faculty members are reluctant to innovate in their teaching if extra time is required. Given this dynamic, efforts to encourage faculty members to change their teaching practices should identify and promote the use of those teaching strategies that research shows to be most effective and easiest to use (Fairweather, 2008). Overwhelming research evidence points to active, engaged learning processes as highly effective in relation to learning outcomes (Kuh et al., 2005; Pascarella & Terenzini, 2005). In a context where time and resources must be used judiciously by institutions and individual faculty members, encouraging many faculty members to move from straight lecture teaching designs to the use of basic strategies that encourage active learning (and are relatively easy to use) results in the greatest gains in learning productivity.

Fairweather (2008) has made this argument effectively and the rationale is compelling.

- Reward Systems

- § Research is convincing that the current reward systems do not encourage faculty to invest deeply in teaching; in fact, reward systems tend to undermine such interest. Institutional leaders should initiate campus-wide conversations about ways to include teaching innovation and demonstrate teaching excellence more fully in evaluation processes and reward systems. Furthermore, the efforts of a teacher to integrate new approaches may not be immediately successful; those experimenting with new approaches to their teaching should not be penalized as they try new strategies to support student learning.

- § Professional societies also can play a role in encouraging these discussions. Changing the dominant reward system is a daunting task, one that has been discussed for more than two decades at the institutional and national levels. Continued national dialogue is necessary, as individual institutions with strong research cultures are unlikely to include greater emphasis on teaching in reward systems if a national movement does not press for this change.

- Leadership Development

- § Deans and department chairs play a major role in creating cultures within their units where teaching excellence is valued and rewarded. They can regularly discuss the relationship of student learning to institutional missions and the relationship of teaching excellence to student learning. They can make work assignments to provide space and time for innovation. They can initiate opportunities for collegial conversations about new teaching approaches and their impact. However, chairs and deans often need guidance in how to assume these leadership roles. Thus, institutions should consider offering on-going professional development opportunities for deans and chairs to grow as leaders who are effective in cultivating cultures in which teaching is valued and innovation encouraged and rewarded.

- Professional Societies and National Networks

- § Professional and scholarly societies and national networks, such as CIRTLL, can be useful levers for encouraging faculty to think in new ways about their teaching and to integrate new methods into their behaviors. First, professional and scholarly societies and national networks provide opportunities for those faculty members interested in discussing teaching or learning new evidence-based practices to connect with each other. The opportunity to participate with

colleagues in such a “safe space” supports and encourages faculty members and doctoral students who are committed to effective teaching practice and may experience resistance to their interest within their home departments. Second, when scholarly and professional societies and national networks highlight the importance of effective teaching practices, they provide symbolic leadership that has the potential to frame national dialogues about teaching within their fields.

- Preparation of Future Faculty

- § One way to change teaching practice is to prepare future faculty who understand learning processes and evidence-based teaching strategies and who value effective teaching as part of their career aspirations. National organizations such as the National Science Foundation encourage doctoral-level preparation for teaching through support for such initiatives as CIRTLL. Research currently underway through CIRTLL and other NSF-sponsored research is examining what kinds of doctoral-level professional development are related to particular outcomes and the long-term impact of involvement in future faculty professional development programs on aspiring faculty.

Important Future Research Directions

Knowing what teaching practices result in student learning is important. Knowing how to get faculty members to use those teaching practices is equally important and essential if the teaching practices are actually going to have the chance to make an impact. Influencing faculty behavior requires understanding the multiple contexts in which faculty members work and the levers with the most potential to affect their thinking and actions. A systems approach that incorporates multiple strategies to affect faculty teaching practice is necessary to encourage faculty members to change.

Future research to promote evidence-based teaching should consider:

- Studies of institutions where evidence-based educational reform is occurring to explore the institutional factors encouraging the reform efforts, barriers to reform and strategies for handling the barriers, the process through which the reform develops, and factors contributing to new teaching practices.
- Studies of various kinds of professional development and the impact of different approaches on change in teaching practice (including the time requirements of various approaches).

- Studies focused on the paths through which individual faculty members change their practice toward evidence-based educational change (including factors encouraging change, barriers the faculty members encounter, and individual strategies used to negotiate the contexts that influence individual practice).
- Studies on the long-term impact of professional development at the doctoral and post-doctoral levels on values and practices in regard to teaching and evidence-based educational reform.
- Development of change models concerning faculty teaching practice and evidence-based change in undergraduate science education that take into account both individual characteristics and contextual factors.

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