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A Framework for Inclusive Teaching in STEM Disciplines

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Abstract

A wide body of literature exists recounting the ways in which inclusive teaching practices and principles benefit students and positively impact learning, student retention, and professional development across disciplines. However, STEM faculty do not readily accept the traditional approach of examining course content from multiple perspectives as relevant to their course content or useful in their teaching. In this chapter, we propose a Framework for Inclusive Teaching in STEM Disciplines that reflects the contexts of teaching in these disciplines, and extends James Banks' Five Dimensions of Multicultural Education to the distinct needs of STEM faculty in their classes. We also discuss ways that faculty development professionals can successfully communicate with STEM faculty about inclusive teaching goals.

Different Ways of Approaching This Chapter

In this chapter we provide faculty developers with a framework for promoting more inclusive teaching in their work with faculty in Science, Technology, Engineering and Math (STEM). Depending on your background, you may find it useful to start at different points in the chapter (Figure 1). People familiar with the STEM literature should begin with Section 1, where we propose a conceptual framework for inclusive teaching in STEM disciplines. People more at home with the literature of diversity and multiculturalism should begin with Section 2, where we briefly describe James Banks' Five Dimensions of Multicultural Education (1996). Instructional development specialists may fit into both these categories (or neither very comfortably). People primarily interested in helping STEM faculty develop more inclusive teaching practices should begin with Section 3, where we provide examples of entry points for talking about inclusive teaching with STEM faculty.

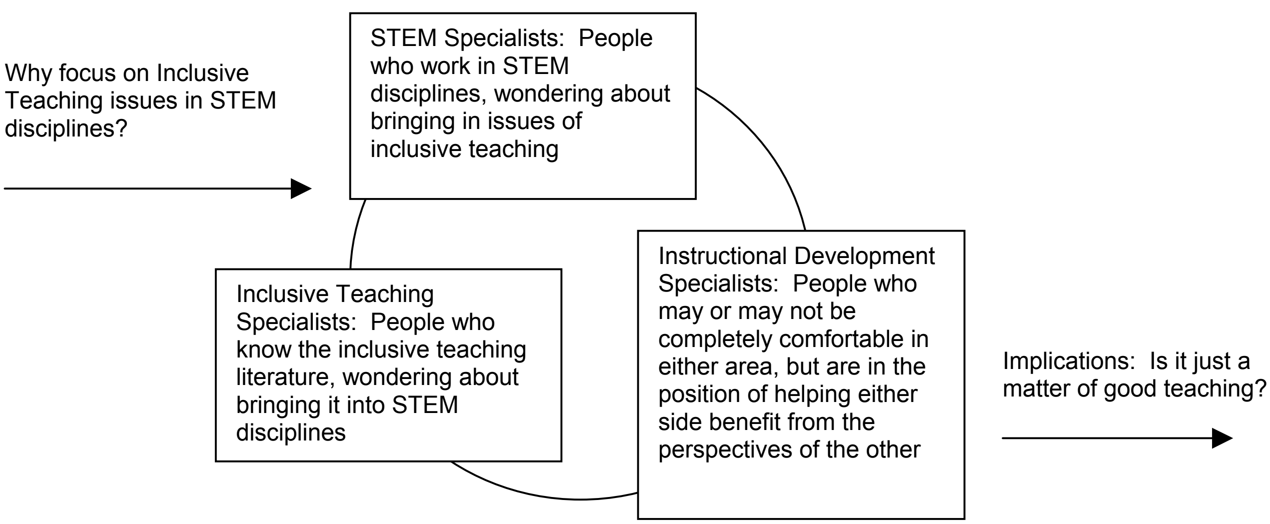

Figure 1: A Reader's Guide to Using this Chapter

Section 1: Why focus on Inclusive Teaching in STEM disciplines?

The lack of racial and ethnic diversity among students and faculty in STEM disciplines is a well-documented, persistent challenge for leaders in STEM education, business, government, and industry (AAAS, 1989; CAWMSET, 2000; George, 1996; NSF/DOE, 1980; Rutherford and Ahlgren, 1990). Many variables impact the population of STEM degree recipients, but three in particular facilitate our discussion of the need for a specific focus on inclusive teaching in STEM: demographic patterns and trends, retention related issues, and economic influences.

Demographics

Current and predicted statistics for student populations in the U.S. highlight the need to attract a more representative sample of students to the STEM disciplines. U.S. citizens are currently the primary student population in postsecondary institutions in the U.S.[1] (NCES, 2003), and the white male segment of that population serves as the primary source of students in STEM disciplines. However, trends in the U.S. population indicate widespread changes for future student populations. The Census Bureau predicts a decrease in the white (non-Hispanic) segment of the U.S. population from 74% in 1995 to 64% in 2020, and 53% in 2050. By 2050, the Latino population will have grown the most, and the African-American population will nearly double in size. The traditional college-age population will grow by 16% between 2000 and 2015 and, of these potential new students, 80% will be non-white and nearly 50% will be Hispanic (BHEF, 2002).

Even without the predicted changes to future populations, the student demographics are already shifting. Over the past 20 years, the proportion of white students enrolled in U.S. undergraduate institutions decreased, falling from 80 percent in 1978 to 70 percent in 1997, while the numbers for underrepresented minorities increased from 16% to 22% (NSB, 2002). Additionally, women outnumber men in undergraduate enrollment for every racial and ethnic group (NSB, 2002) and over 57% of undergraduate students have characteristics that identify them as non-traditional students (NCES, 2002).

Retention

The number of degrees awarded in the natural sciences and engineering has steadily decreased since the mid-1980s (NSB, 2002) and projected increases in the population of 18-24 year olds will not reverse this trend without attention to the ability of STEM fields to attract and retain a broader, more representative portion of the population. Of particular concern are the lower completion rates for women and students from groups traditionally underrepresented in STEM fields (Cohoon, 2001; Montgomery & Barrett, 2002). Students from underrepresented groups switch to other disciplines at higher rates and have lower completion rates than white and Asian American students (Clewell & Campbell, 2002; Seymour and Hewitt, 1997). The National Science Board reports lower retention and degree completion rates in science and engineering for both women and students from underrepresented groups (NSB, 2002).

Some might assume that retention and completion rates are low because the students who change majors or drop out of college are under prepared or incapable of meeting rigorous STEM requirements. In fact, many of those who switch are academically equal to or more advanced than students who stay (Seymour & Hewitt, 1997) and these “switchers” may be opting out of STEM based on negative experiences in college and discouraging observations of STEM professionals (Clewell & Campbell, 2002; Nauta, Epperson, & Kahn, 1998). Still others suggest that non-majority students are simply not interested in STEM careers. However, studies of entering freshmen indicate a relatively even distribution of interest in science and engineering (NSB, 2002), and that white, African American, Asian American, and Latino high school seniors take similar numbers of science and mathematics courses (Clewell & Campbell, 2002).

Economics

The systematically low completion rates for women and minorities, even during economically prosperous times, belies the oft repeated anecdote that first-generation students attend college and select majors in order to achieve economic prosperity. If money were a promising means to attract students from underrepresented groups, we would not have students from groups underrepresented in STEM entering the less lucrative social sciences at higher rates (NSB, 2002). It is evident that we cannot rely on the prospect of lucrative careers to rectify the imbalance between general population, student population, and STEM demographics.

Overall, the decrease in degree production by U.S. institutions of higher education has resulted in a failure to keep up with the demands of business, industry, and government for qualified employees (NCES, 2002). In 1998, Dr. Vernon Ehlers, Representative and Vice Chairman, Committee on Science,

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[1] In 1999-2000, foreign-born students in postsecondary institutions constituted only 11%of the undergraduate student population.

U.S. House of Representatives, pointed out at a National Science Policy Hearing that a crisis is looming in the U.S. science and engineering enterprise. He predicted that the demand would soon exceed the supply of new scientists and engineers and that the economic health of our nation would suffer as a result. Projections indicate that by 2028, there will be 19 million more jobs than workers adequately prepared to fill them (BHEF, 2002).

Framework for Inclusive Teaching in STEM Disciplines

In light of these demographic, educational, and economic trends, it is important for instructors in STEM disciplines to teach in ways that include all students and encourage them to continue in the discipline. The reasons why students feeling excluded are numerous and complex, and our goal is to provide a framework to help instructors identify, assess, and improve teaching practices that are likely to have the greatest impact. Our Framework for Inclusive Teaching in STEM disciplines consists of five interrelated dimensions, outlined in Table 1, and begins with accurate Problem Definition.

Table 1: Five Dimensions of Inclusive Teaching in STEM Disciplines

Problem Definition	Clearly identify goals, rationales, starting conditions, appropriate design, and principles of implementation to achieve optimal learning outcomes.
Redundant Systems	Recognize that an effective system is designed to monitor and respond to feedback, adapt to changing conditions, and provide alternate strategies when systems do not function or other obstacles are encountered.
Expert Practice	Establish that your design and approach to teaching support effective learning of course content for all students.
External Constraints	Anticipate and minimize or compensate for ways in which teaching and learning processes and outcomes are influenced by environmental factors and other external constraints.
Comprehensiveness	Maintain thoroughness and rigor of what is taught, grounded in actual (rather than idealized) conditions.

Accurate Problem Definition

With Problem Definition, we ask STEM faculty to examine course design through a process of inquiry. We begin with two familiar first steps: identifying what is important for students to know, and explicitly articulating why that information is important, but we extend this process by asking faculty to consider the ways in which students achieve mastery in their particular discipline. This includes the examination of students' learning patterns, the conditions under which students adopt new models of thinking, and the relationships among students' mastery of conceptual knowledge, problem-solving ability, and levels of engagement. We also ask faculty to establish consistency between these learning issues and their course goals, content, activities, and evaluation methods through attention to what is taught, modeled, and graded since students typically identify what is important by observing these three areas. For example, research shows that expert problem solvers develop conceptual maps prior to tackling problems while novices begin by immediately attempting to find solutions (Breslow, 2001). Another study indicates that successful problem solvers view mistakes and failure as necessary steps to improve problem solving skills (Born, Revelle, & Pinto, 2002). Armed with this knowledge, an instructor may identify conceptual thinking as a stated goal and discourage students from viewing mistakes as failure, but if class time, projects, and tests emphasize memorization, repetition, and summative forms of evaluation, then students will likely conclude that memorization, repetition, and perfection are most important.

Provision of Redundant Systems

The second dimension of our Framework for Inclusive Teaching is the provision of Redundant Systems. This dimension asks STEM faculty to recognize that even well-designed systems face unanticipated obstacles, making it necessary to provide more than one means to a desired end. This realization can stimulate consideration of multiple means of facilitating student success: for example, some students learn relatively more from interactive lectures, others through peer collaboration, and still others from hands-on experience. Ultimately, this dimension of the Inclusive Teaching framework asks instructors to design learning experiences based not just on how they have taught before or how they originally learned the material themselves, but on the complexity of the learning goals and full range of students' capacities to learn.

A second implication of providing Redundant Systems is that instructors should be prepared to provide appropriate support for those learning outcomes that require particular learning experiences. To return to the example of collaborative design, students who prefer to learn through interactive groups may need little or no additional support to learn effectively on a design team. However, students who prefer to work individually are unlikely to benefit from collaborative work simply by being told to "form a group." Students in this situation are much more likely to learn how to work collaboratively if they are given well-designed support to help them define tasks, assign individual roles and responsibilities on the team, and assess outcomes of the team's work. For example, Born, Revelle, & Pinto (2002) found that successful interventions for improving student performance in biology included weekly workshop groups that were academically rigorous (non-remedial), cooperative (non-competitive), and facilitated by trained student peers who had successfully completed the course and who provided encouragement and guidance without giving answers.

Expert Practice

The third dimension of our Framework for Inclusive Teaching is Expert Practice, defined here as the demonstration that teaching practices are not biased to favor particular outcomes for particular learners, but rather, are designed to support effective learning for all students who do what is required for the course. Many instructors may believe that their classrooms provide neutral conditions for learning, but research (Marx, Brown & Steele, 1999) demonstrates that some learners come into STEM classrooms expecting to find it biased against them – students often expect classrooms to favor students who are most like the instructor (traditionally white and male). With Expert Practice, instructors proactively demonstrate that all students have equal opportunity to learn (not just those who are similar to the instructor).

This demonstration can be as straightforward as making explicit statements that the course design and approach to teaching support all students who do what is required for the course. Another useful practice is for the instructor to make explicit statements about personal challenges and what he or she has done to learn successfully. In this way, you remind students that the subject matter did not "come naturally" to you, but rather, it required learning particular sets of skills, over a certain period of time, and with a considerable amount of effort. Within this context, effective strategies also include providing students with feedback that is task specific and not a general confirmation of natural ability. For example, an instructor may tell a student that her thinking demonstrates a clear understanding of a given concept rather than responding with general statements like "good", which can associate performance with student identity and not specific learning.

Management of External Constraints

The fourth dimension of our Framework for Inclusive Teaching is the management of External Constraints, which involves minimizing or compensating for direct and indirect environmental affects on processes and outcomes. This dimension aids STEM faculty in dealing with the numerous factors, which may only be indirectly related to the instructor's teaching practices, but are affecting the students before they take a course and while they are taking it.

One critical external constraint is student preparation. Students' prior learning experiences are clearly beyond an individual instructor's control, but that limitation does not preclude gathering data on those experiences and taking them into account while teaching. One such case involves a study that investigated predictors of women's higher level career aspirations in mathematics, science, and engineering majors. It found that the relationship between ability and higher level career aspirations could be positively influenced through attention to students' feelings of self-efficacy (Nauta, Epperson, &

Kahn, 1998). Simply stated, female students had the tendency to view their STEM performances less positively and less accurately in relation to other students, and aiding these women in developing more accurate and positive pictures of their performances strengthened their commitment to future endeavors in STEM disciplines. While STEM faculty may be unable to control the quality of students' prior STEM experiences, with knowledge of such studies, they can positively influence the ways in which students view their learning potential and their past and present performances.

Another important external constraint on student learning is the presence of other students. Montgomery & Barrett (2002) found that negative peer interactions (e.g., feelings of isolation, and perceptions of resentment from male students) have detrimental effects on women students in undergraduate science and engineering courses. If particular students are left on their own while others form project teams, or are routinely assigned less desired roles on team projects, these students will quickly get the message that their contributions are not valued. Similarly, students who volunteer answers or raise questions during lecture, but observe that other students routinely disregard or disrespect their contributions, may easily conclude that they are not welcome in the class.

Outside the classroom, External Constraints include departmental factors such as advising practices, and mentoring opportunities. Women, for example, generally report fewer opportunities for positive student-faculty interactions and supportive advising (Montgomery & Barrett, 2002). Department facilities can also be a factor, such as whether or not the building provides a place for students to work together between classes, or even provides a sufficient number of women's restrooms. One department review revealed female students' frustration over the number of male students using the computer lab to access internet pornography.

For an individual instructor, control over these External Constraints is limited, but minimizing their effects or otherwise compensating for them is still possible. Those that are related to classroom learning can be addressed by the instructor's decisions about how to establish groups, or how to respond to individual students' contributions to class. Out-of-class constraints may be harder to deal with, but instructors can bring departmental issues to the attention of appropriate decision-makers (in the case of the restrooms), or take the lead in establishing an ethic of professionalism, respect for fellow students, and respect for university's stated policies (in the case of the internet pornography).

Comprehensiveness

The fifth dimension of our Framework for Inclusive Teaching is Comprehensiveness; ensuring that what is taught is rigorously grounded in actual (rather than idealized) conditions, which include contexts in which learning outcomes, applications, or practices will be used, and also their ethical or social implications. Instructors who avoid discussing the ethical and social relevance of their work do a disservice to their students by communicating that students who are concerned with these issues are somehow less important members of the professional or scientific community.

Similarly, it may not occur to some instructors that the history and development of their discipline has been shaped by a diverse community of professionals and scholars, and attention to thoroughness and rigor requires that these contributions to the profession be duly acknowledged. In a course, the emphasis remains on what one does as an expert in this field, rather than on whom one is; however, it is still important to proactively demonstrate that people of all types have been successful. To give one example, a white male professor can show through attention to principles of Expert Practice that successful learning is not contingent upon being either white or male. He may also utilize scholars of color as guest lecturers, or former students of color as peer mentors. One study found that the mere presence of women proctoring a difficult mathematics exam diminished the impact of stereotype threat and underperformance for female test takers (Marx, Brown, Steele, 1999). This attention to Comprehensiveness adds the positive message that it is possible to succeed as a female or a person of color, provided that the learner is willing and enabled to do the work of learning in this discipline.

Section 2: James Banks' Five Dimensions of Multicultural Education

In developing our Framework for Inclusive Teaching in STEM Disciplines, we have drawn heavily on James Banks' (1996) dimensions of multicultural education (Table 2). Banks' model has been widely applied in K-12 settings, and we have found it highly relevant to STEM disciplines at the college level. However, we have also observed that many STEM faculty do not readily recognize its relevance to teaching in their disciplines because of the terms in which it is expressed.

Table 2: Five Dimensions of Multicultural Education (Banks, 1996)

Content Integration	Utilize resources from a diverse range of cultures and groups to illustrate course concepts and ideas.
Knowledge Construction	Facilitate students' understanding of the value-laden assumptions and biases operating within a given field or discipline.
Prejudice Reduction	Create learning environments that foster students' rejection of negative racial attitudes and values.
Equity Pedagogy	Adopt, integrate, and develop a set of teaching skills and techniques that reflect consideration of the full range of cultural perspectives and practices that influence student learning.
Empowering School Culture	Re-envision and restructure educational institutions to promote equity in learning and cultivate respect for students' backgrounds and cultural experiences.

According to Banks, multicultural education involves attention to five major areas (Table 2): Content Integration, Knowledge Construction, Prejudice Reduction, Equity Pedagogy, and Empowering School Culture. Content Integration (see Comprehensiveness in STEM framework) promotes the examination of course content from a range of cultural perspectives and is frequently viewed as the salient feature in multicultural education. Extending thinking beyond content, the knowledge construction process (see Problem Definition) requires both faculty and students to uncover and explore the value-laden assumptions and biases within a discipline. The knowledge construction process challenges the thinker to examine critically not only what is taught, but also the contexts of who, how, why, when, and where.

Prejudice Reduction (see Expert Practice), or attention to the characteristics of students' racial attitudes and values, focuses on relationships with and among students. For faculty, prejudice reduction involves identifying potential barriers to student success, emphasizing students' individual strengths, and creating clear expectations for learning in the classroom. Equity Pedagogy (see Redundant Systems) addresses the use of teaching skills and techniques that reflect multiple learning styles and the various strategies that have proven effective for recruitment and retention of underrepresented students.

Empowering School Culture (see External Constraints) involves re-envisioning and restructuring educational institutions to promote equity in learning and cultivate respect for students' backgrounds and cultural experiences. Attention to students' learning on an organizational level implies questioning assumptions about student achievement, and also providing opportunities for meaningful interactions with and among students both academically and socially.

Section 3: Talking About Inclusive Teaching with STEM Faculty Using Banks' Framework

We suggest that faculty developers can provide leadership to help bring more inclusive practices into STEM classrooms. To support that goal, we propose our Framework for Inclusive Teaching as a tool for faculty developers with two distinct uses. First, this framework provides a set of guiding questions that directly relate to contexts of teaching in STEM disciplines, allowing faculty developers to raise questions about features such as course goals, rationale, starting conditions, and appropriate design – areas in which many faculty developers are already successfully working. Beyond that, we suggest using this framework to define not just what we talk about with STEM faculty, but how we talk about it when we work with them.

In our framework, we make Problem Definition first (Table 3), recognizing that knowledge construction for many in the STEM disciplines revolves around questions of inquiry: problem definition, design, data collection, and analysis. Because problem definition provides a familiar language for STEM faculty to reflect on knowledge construction, faculty developers can begin by making our case to them on these terms.

Table 3: Dimensions of Multicultural Education in Comparison with Dimensions of Inclusive Teaching in STEM Disciplines (Banks, 1996)

Knowledge Construction Process	⇔	**Problem Definition**
Equity Pedagogy	⇔	**Redundant Systems**
Prejudice Reduction	⇔	**Expert Practice**
Empowering School Culture	⇔	**External Constraints**
Content Integration	⇔	**Comprehensiveness**

In addition to using familiar terminology, we also propose establishing a case for inclusive teaching by drawing on a central feature of knowledge construction within these disciplines: referral to evidence and recognized sources of data. For example, faculty developers may use ABET criteria and career surveys that show the importance of working collaboratively, or discipline-specific arguments for greater diversity within the field. Other sources of data could include research on the effectiveness of current programs and practices. For example, Seymour and Hewitt (1997) identified reasons females leave STEM disciplines including changed interest, being “turned off”, poor teaching, and inadequate advising. By starting with the data, and making faculty aware of the large body of research available to them, it is possible to present exclusive teaching as a problem for which they need to design a solution. Faculty developers can also challenge STEM faculty to plan their courses in ways that allow them to collect data on the inclusive nature of their own teaching. Because of the ways that knowledge is constructed within these disciplines, this approach opens an avenue for change which is both familiar and valued.

Our framework also proposes approaching faculty with consideration for Redundant Systems, acknowledging that faculty learn and change in different ways, and at different rates. Some will change on the basis of empirical evidence, while others will be more motivated by piloting a series of changes and assessing outcomes. In any case, faculty change, like student learning, is rarely immediate or complete based on a single experience.

Our own Expert Practice as faculty developers must include a healthy respect for faculty defenses against perceived prejudice, helping STEM faculty manage the threat of talking about diversity. Just as students may feel a learning situation is prejudiced against their success, so faculty may feel they have been pre-judged and feel resistant to change, uninterested in diversity, or unconcerned about social justice. (Just as students may have good reasons for their perceptions of prejudice, so too, faculty may have experienced being labeled in these ways.) One approach is to explicitly acknowledge unspoken accusations and share experiences managing this perceived threat. A second approach involves introducing the issue of diversity by honoring what faculty are already doing which contributes successfully to inclusive teaching and encouraging continued development.

Additionally, we need to acknowledge the External Constraints influencing faculty change, and be prepared to extend our consulting beyond an individual instructor. Key elements for consideration include the departmental climate for faculty – not only for women and faculty of color, but also to place a higher value on learner-centered teaching, Scholarship of Teaching and Learning, and non-traditional STEM approaches to achieving learning outcomes such as group process, interdisciplinary problem-solving, communication, and decision-making. We can also help faculty who are committed to inclusive teaching become their own advocates by helping them gather and present data in ways that will help them make effective cases for change within their departments.

Finally, we have found that faculty members who equate inclusive teaching with content integration often conclude that the literature on inclusive teaching is not relevant to their teaching. We challenge this conclusion, but also recognize that for many faculty members it is not the most compelling place to begin. Our model recognizes this by addressing the issue in terms of Comprehensiveness, and addressing it last, rather than first.

Is Inclusive teaching really just Effective Teaching?"

We recognize that it might be possible to review our Framework for Inclusive Teaching in STEM Disciplines and conclude that inclusive teaching is synonymous with effective teaching. We can agree with that conclusion, but only in part. We are not suggesting that someone who is teaching effectively is, incidentally, also teaching inclusively. Inclusive teaching represents a set of principles, goals, and practices grounded in research, experience, and commitments to social justice. Within this broader set of principles, goals, and practices is a subset which might be identified as effective teaching practices. Because effective teaching fits within this broader framework of inclusive teaching, there will not be a conflict between the two, and in fact it may be difficult to distinguish one from the other simply by looking at a sample of teaching practices.

Inclusive teaching adds to effective teaching a framework for understanding why teaching is effective, which in turn helps solve problems, extends effective practices to other contexts, and facilitates adapting to change. For example, a faculty member may teach a course effectively without consciously considering inclusiveness, but by defining the problem well, this faculty member has created a learning environment which effectively welcomes and includes all students. However, being effective in one course does not guarantee being effective in a different course, at a different level, or with a different group of students. Inclusive teaching provides categories for description and analysis when something is discovered to be ineffective, even though it that has been effective at another time, in another course, or with another group of students. Inclusive teaching encourages faculty to be explicit in their decision-making about teaching – beyond "doing what worked last time."

As faculty developers, we would like the faculty we work with to teach effectively, but we would also like to see them do better than that. By using this Framework for Inclusive Teaching to guide our work and even the nature of our interactions with STEM faculty, we hope to provide them with a way to understand what is effective, and why, for including all students in opportunities to learn.

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