TRANSFORMING THE CULTURE OF THE STEM DISCIPLINES: A MULTIPLE CASE STUDY OF SUCCESSFUL STRATEGIES FOR INCLUSIVE EXCELLENCE

by

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DEDICATION

To my mom, Wylene A. Broomfield, my first teacher – You instilled in me a love for learning at an early age. I will never forget the flash cards you made out of Daddy's business cards. From those first phonics lessons to the many life lessons you have taught me since, I am eternally grateful. I cherish our relationship and love you so much!

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ABSTRACT

In spite of the myriad initiatives promoting diversity and inclusion in science, technology, engineering, and math (STEM) disciplines at colleges and universities across the country and the increased funding for these types of initiatives, colleges and universities have experienced modest gains and, in some cases, slight declines in the graduation rates of women and underrepresented minorities (URMs). In addressing this issue, some institutions rely on traditional or "deficit" approaches that place primary responsibility on students for their success in the STEM fields. A growing number of institutions, however, embrace the concept of inclusive excellence, which is an assumption that underrepresented students can and will rise to high expectations provided institutions have a better understanding of and commitment to fostering the conditions in which these students thrive. Although there is much in the literature about successful programs and initiatives in the STEM disciplines that are aligned with the concept of inclusive excellence, there is little information about the organizational change processes that ensure that these initiatives are implemented on a scale large enough to significantly impact the enrollment and graduation rates of women and URMs.

This study addressed the void in the literature through a multiple case study of three departments/schools at elite Predominantly White Institutions that have had success with enrolling and graduating women and underrepresented minorities (URMs) at rates above the national average – the computer science department at Harvey Mudd College, the physics department at the Massachusetts Institute of Technology, and the Cockrell

School of Engineering at the University of Texas Austin. Employing qualitative content analysis as the methodology, 246 documents from these institutions were analyzed both deductively with the Transformational Change Model for Inclusive Excellence as a framework and inductively to determine the strategies that advanced initiatives in the model departments and school.

Analysis revealed that each department/school utilized, to some degree, strategies from the framework, including understanding and articulating the rationale for change, securing senior administrator buy-in, collaborating across multiple departments and disciplines, providing professional development for those associated with initiatives, focusing attention on the environment for underrepresented students, developing a vision for the department/school that was flexible and modified when needed, engaging in high impact and visible actions that were staged over time, and conducting comprehensive assessment and evaluation. Beyond the framework, analysis revealed that campus culture, external funding, and selective admissions also played a role in advancing initiatives on a large scale, as did other factors that were specific to each institution.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AIAN ...... American Indian/Alaska Natives

CS ...... Computer Science

CSE ...... Cockrell School of Engineering

EOE ...... Equal Opportunity in Engineering Program

FIG ...... First-Year Interest Group

GIR ...... General Institute Requirements

GLUE ...... Graduates Linked with Undergraduates in Engineering

HBCUs ...... Historically Black Colleges and Universities

HMC ...... Harvey Mudd College

HSIs ...... Hispanic Serving Institutions

IECPI ...... Inclusive Excellence and Change in Postsecondary Institutions (Model)

MIT ...... Massachusetts Institute of Technology

MSIs ...... Minority Serving Institutions

NHOPI ...... Native Hawaiian or Other Pacific Islander

OME ...... Office of Minority Education

PWIs ...... Predominantly White Institutions

STEM ...... Science, Technology, Engineering, and Mathematics

TCMIE ...... Transformational Change Model for Inclusive Excellence

URMs ...... Underrepresented Minorities

UT-Austin .... University of Texas at Austin

WEP .... Women in Engineering Program

CHAPTER 1
The Nature And Scope Of The Study

> "Culture does not change because we desire to change it. Culture changes when the organization is transformed; the culture reflects the realities of people working together every day" (Hesselbein, 1999, p. 6).

> "There is nothing more difficult to take in hand, more perilous to conduct or more uncertain in its success, than to take the lead in the introduction of a new order of things" (Machiavelli, 1515, Chapter VI, para. 5).

These quotes from Hesselbein and Machiavelli, though written centuries apart in different contexts, illuminate the universal complexities associated with organizational change. They suggest that having a "big idea" is not enough to facilitate change in an organization; rather, there is a system of actions involved with developing that idea to fruition in complex environments that, for varying reasons, may be resistant to change. Such is the case with implementing undergraduate programs designed to increase the graduation rates of women and underrepresented minorities (URMs) in science, technology, engineering and math (STEM) disciplines. In the case of women and URMs, the "big idea" is clear. The graduation rates of women (in particular STEM disciplines) and URMs are disproportionately below those of their peers, and colleges and universities are searching for ways to address this problem.

In spite of the myriad initiatives aimed at broadening participation in the STEM disciplines at the postsecondary level, colleges and universities have experienced modest gains and, in some cases, slight declines, particularly in the graduation rates of women and URMs (NSF, National Center for Science and Engineering Statistics, 2013). In many cases, the programs seem to operate at the periphery of the core academic functions of STEM departments/schools, failing to penetrate or transform the culture.
Clayton-Pedersen and Musil (2005), in their introduction to the AAC&U's Making Excellence Inclusive initiative, referred to programs such as those that operate at the periphery as "islands of innovation." According to them,

> new research about how to help diverse and differentially prepared students succeed has not yet provoked widespread change across higher education. And diversity is not typically a focus at any level in "quality improvement" efforts. As a result, education leaders routinely work on diversity initiatives within one committee on campus and work on strengthening the quality of the educational experience within another. This disconnect serves students—and all of education—poorly (p. vii).

This "disconnect" also underscores the importance of understanding how the change process unfolds with regard to diversity and inclusion initiatives and which strategies are most effective within the context of the STEM disciplines.

Purpose

There is little in the literature that highlights the organizational change processes faculty, staff, and administrators in the STEM disciplines utilize to broaden participation in these disciplines, how these processes impact the success of their initiatives, and the barriers they encounter along the way. This study will address the void in the literature by examining the process by which faculty, staff, and administrators in academic departments/schools at three elite, Predominantly White Institutions (PWIs) achieved success at increasing enrollment and graduation rates among women and/or URMs.

Since 2005, the Computer Science Department at Harvey Mudd College (HMC) in Claremont, California , a small, private liberal arts college with the distinction of being a premier engineering, science, and mathematics college, increased its enrollment of women from 12 percent to 40 percent and also achieved a career/graduate school placement rate of 100 percent (Harvey Mudd College, 2014a, 2014b). The Department of Physics at the Massachusetts Institute of Technology (MIT), a research university with very high research activity, increased female enrollment from 17 percent in 2001 to nearly a third since then and increased the percentages of female graduates and underrepresented minorities to 38 percent and 13 percent, respectively, both of which are well above the national average for physics (Bertschinger, 2012). Similarly, during the 2012-2013 academic year, the Cockrell School of Engineering at the University of Texas Austin (UT-Austin) awarded 15.9 percent of its degrees to URMs and 21.7 percent to females, both of which are above the national average for engineering (Berry & Dominguez, 2013). They also boasted rigorous research experiences for these students and, in 2010, achieved a career/graduation placement rate of 90 percent (UT-Austin, Cockrell School of Engineering, 2010).

Research Questions

Given the success of these institutions in attracting women and URMs to STEM disciplines, retaining them to graduation, and facilitating their placement in the STEM professional workforce, the operational approaches within these departments and school deserve a close look. Thus, the research questions guiding this study include the following:

1) What strategies did faculty, staff, and administrators at each model institution use to increase enrollment and graduation rates among women and/or underrepresented minorities in their respective departments/school?
2) In what sequence and to what extent were these strategies used to produce the desired changes?
3) What, if any, barriers did those responsible for implementing initiatives face, and what strategies did they use to overcome these barriers?
4) How were the strategies and barriers similar and/or different across institutions?

Significance of Study

Quality of life issues among women and URMs undergird the importance of transforming the culture of the STEM disciplines to be more inclusive. According to a report by the U.S. Department of Commerce (Langdon, McKittrick, Beede, Kahn & Domas, 2011), in 2010, the average STEM worker earned 26 percent more than non-STEM workers, and employees with STEM degrees had higher earnings whether working in STEM or non-STEM jobs. Job growth between 2008 and 2018 was projected to be 17 percent in comparison to 9 percent growth in non-STEM disciplines. In addition, unemployment in the STEM occupations was lower than that for non-STEM occupations. Considering that women and minorities are disproportionately represented among the poor and unemployed (Center for Postsecondary and Economic Success, 2013; U. S. Bureau of Labor Statistics, 2013), the STEM disciplines offer opportunities for economic advancement that could greatly enhance quality of life for women and minorities.

In addition to the economic impact to individuals and communities, quality of life also pertains to innovations geared toward diverse populations. Without representation of women and URMs, innovations of the future may not adequately reflect the needs of women and URMs, many of which may differ from those of White males. Additionally, the types of skills cultivated in the STEM disciplines - researching topics and determining reliable sources, recognizing cause and effect relationships, predicting and drawing conclusions based on data, and thinking creatively to solve problems (Texas GEAR Up, 2014) - not only influence how a person in the STEM approaches her/his job but also how that person approaches problems in general, which, given the disparities facing women and minorities, is a skill set direly needed.

Because the STEM disciplines offer such promise for women and URMs, it is important that faculty, staff and administrators who are involved with and interested in broadening participation in the STEM disciplines have a thorough understanding of how to facilitate systemic change. Securing funding for and implementing initiatives that have been identified in the literature as effective do not ensure that the initiatives will be widely accepted and duplicated throughout the department so as to have the desired impact on the enrollment and graduation rates of women and URMs. Based on their extensive research on organizational change strategies at postsecondary institutions, Eckel, Green, Hill and Mallon (1999) observed that

> [t]hose who have undertaken the journey [of organizational change] often find that the difficulty in accomplishing change—and, frequently, the reason it fails—

> is not because of a lack of either vision or good ideas about what to do, but rather because the change process is often hard to comprehend and manage. The substantive set of issues an institution is working on and the goals it seeks to achieve are only two parts of the puzzle. A key piece is the process. Most of the time, institutional leaders are thinking about what to do, rather than how to do it. Strategy and process are afterthoughts, and too often are simply ignored (p. v.).

This study seeks to ensure that strategy and process are not merely afterthoughts by examining the processes used in the model departments/school through the lens of the Transformational Change Model for Inclusive Excellence, the framework developed for this study. This framework builds on previous models that have been utilized in higher education contexts and focuses specifically on strategies for approaching change with attention to issues of inclusion and excellence. Using this model to frame the study challenged and affirmed common assumptions about strategies for organizational change, revealed insights that are overlooked in discussions about diversity and excellence, and provided information to inform the practices of faculty, staff, and administrators contemplating the process of addressing issues of inclusion in the STEM disciplines at their respective institutions.

Clayton-Pederson and Musil's (2005) observations about growing interest in understanding the change process summarize the significance of this study:

> One frequently can identify educational innovations, but rarely can one detect structures that link them. Accordingly, the impact of these innovations is isolated rather than pervasive. And with so many individual diversity initiatives springing up like daffodils in springtime, people long for coherence, cohesion, and

collaboration. They also want to figure out how to "get it right" as they move through this astounding transition to an inclusive academy that strives for diversity and excellence (p. vii).

Background of Study

In the continued aftermath of the 2008 recession, characterized by prolonged and inflated unemployment, slow job growth, and increased demand for federal assistance to individual citizens and various industries, the national dialogue about improving the economy includes strategies for increasing the number of students who pursue and obtain degrees in the STEM disciplines at colleges and universities across the country. Numerous reports from government agencies, business and industry groups, and higher education associations assert that the STEM disciplines offer long-term solutions for addressing pressing issues related to the economy (Bayer Corporation, 2012; Business-Higher Education Forum, 2010; Hess, Kelly & Meeks, 2011; National Governor's Association, 2011; President's Council of Advisors on Science and Technology, 2010; Sullivan, Laird, Zimmerman, 2010; U.S. Department of Education, 2008). These reports suggest that individuals with degrees in the STEM disciplines boast lower unemployment rates, higher wages, and career flexibility and that STEM professionals drive innovation that influences U.S. economic growth and global competitiveness.

Statistics on women and URMs in the STEM disciplines.

With regard to women and URMs and how they fit into this national emphasis on organizational change in the STEM disciplines, it is important to understand the conditions that are the impetus for such change. Population statistics, college enrollment, and freshman intention to major in the STEM disciplines, as well as graduation and employment rates in the STEM disciplines all shed light on the relatively low numbers of U.S. residents in the STEM disciplines, in general, and, more specifically, on the scarcity of women and URMs in these disciplines. [Note: Based on the National Science Foundation's broad categorization of STEM disciplines and for purposes of this study, STEM disciplines refer to agricultural sciences; biological sciences; computer sciences; earth, atmospheric, and ocean sciences; engineering; mathematics and statistics; physical sciences – astronomy, chemistry, and physics; psychology; and social sciences – anthropology, area and ethnic studies, economics, history of science, linguistics, political science and public administration, and sociology. Additionally, underrepresented minorities in the STEM disciplines include American Indian/Alaska Native, Black/African American, Hispanic/Latino, Native Hawaiian or Other Pacific Islander. (NSF, NCSES, 2013).]

Although women comprised slightly more than half of the population of U.S. residents in 2012 and over half the college population in 2010, the rate of their intention to major in the STEM disciplines (33.5 percent) was lower than that of males (45.8 percent) in 2012 (NSF, NCSES, 2013). Similarly, even though women earned over half the bachelor's degrees in the STEM disciplines in 2012, disaggregating the data reveals that they were underrepresented in computer sciences (22.3 percent), engineering (19.2 percent), and physics (23.6), among other disciplines. Beyond college, females were employed at much lower rates in STEM occupations (24.1 percent) than their male counterparts (75.9 percent). Table 1.1 and Table 1.2 detail these figures.

Table 1.1

Percent Distribution of Females and Males in Various Populations

	General Population (2012)	**College Population (2010)**	**College Population Intending to Major in STEM Disciplines (2012)**	**Population with Bachelor's Degree in STEM Disciplines (2012)**	**Population Employed in STEM Occupations (2011)**
Female	50.8	56.8	33.5	50.5	24.1
Male	49.2	43.2	45.8	49.5	75.9

Note. Adapted from *Women, Minorities, and Persons with Disabilities in Science and Engineering: 2013* (Special Report NSF-13-304) published by the National Science Foundation, National Center for Science and Engineering and retrieved from http://www.nsf.gove/statistics/wmpd/.

Table 1.2

Percent Distribution of Bachelor's Degrees by Gender: 2012

Field of Study	**Females**	**Males**
All Disciplines	57.4	42.6
All STEM Disciplines	50.5	49.5
Agricultural Sciences	53.6	46.4
Biological Sciences	59.3	40.7
Computer Sciences	22.3	77.7
Earth, Atmospheric, and Ocean Sciences	39.1	60.9
Mathematics & Statistics	43.1	56.9
Physics	23.6	76.4
Psychology	76.7	23.3
Social Sciences	54.7	45.3
Engineering	19.2	80.8
Non-STEM Disciplines	60.4	39.6

Note. Adapted from *Women, Minorities, and Persons with Disabilities in Science and Engineering: 2013* (Special Report NSF-13-304) published by the National Science Foundation, National Center for Science and Engineering and retrieved from http://www.nsf.gove/statistics/wmpd/.

In 2012, URMs comprised one third of the population of U.S. residents and the college population in 2010. Notably, Asian students (52.7 percent) and Hispanic students (41.6 percent) intended to major in the STEM disciplines at higher percentages than White students (37.0 percent), Black students (36.4 percent), and American Indian/Native Alaskan students (33.0 percent). Additionally, White students (62.7 percent) earned most of the bachelor's degrees in the STEM disciplines in 2012, followed by Asian students (18.7 percent), Hispanic students (5.2 percent), Black students (4.6 percent), Other students (1.4 percent), and American Indian/Alaska Native students (0.2 percent). The statistics related to URMs were particularly pronounced considering Asian students earned a higher percentage of the bachelor's degrees in the STEM disciplines, even though their percentages in the general and undergraduate populations were lower than those of other minorities, with the exception of American Indian/Native Alaskans (NSF, NCSES, 2013). For this reason, Asian students are not considered underrepresented minorities with regard to the STEM disciplines.

URMs were even scarcer in the STEM workforce. The majority of U.S. residents with bachelor's degrees in the STEM disciplines and who were employed as scientists and engineers were White (69.9 percent), followed by Asian employees (18.7 percent), Hispanic employees (5.2 percent), Black employees (4.6 percent), Other employees (1.4 percent), and American Indian/Native Alaskan employees (0.2 percent) (NSF, NCSES, 2013). Table 1.3 delineates these figures.

Table 1.3

Percent Distribution of Ethnic Groups in Various Populations

	General Population (2012)	**College Population (2010)**	**College Population Intending to Major in STEM Disciplines (2012)**	**Population with Bachelor's Degree in STEM Disciplines (2012)**	**Population Employed in STEM Occupations (2011)**
AIAN	0.7	0.9	33.0	0.6	0.2
Asian	50	5.7	52.7	9.7	18.7
Black	12.3	13.7	36.4	8.8	4.6
Hispanic	16.9	14.2	41.6	10.3	5.2
Other	1.9	9.1	-	7.9	1.4
White	63.0	56.3	37.0	62.7	69.9

Note. Adapted from *Women, Minorities, and Persons with Disabilities in Science and Engineering: 2013* (Special Report NSF-13-304) published by the National Science Foundation, National Center for Science and Engineering and retrieved from http://www.nsf.gove/statistics/wmpd/.

Factors contributing to attrition in the STEM disciplines.

Scholars, as evidenced by an abundance of literature, have identified numerous factors thought to contribute to attrition in the STEM disciplines. Some of these factors are common to both females and URMs, including cultural isolation, cultural incongruence, lack of critical mass, and/or inadequate support systems (Cole & Espinoza, 2008; Fries-Britt, Younger & Hall, 2010; Lagesen, 2007; Maton, Pollard, McDougall Weise & Hrabowski, 2012; Museus & Liverman, 2010; Strayhorn, 2010; Villareal, Cabrera & Friedrich, 2012). Other common factors include a lack of self-efficacy or confidence in abilities (Baber, Pifer, Colbeck, & Furman, 2010; Byars-Winston, Estrada,

& Howard, 2008; Cole & Espinoza, 2008; Fries-Britt, Younger & Hall, 2010; Litzler & Young, 2012), as well as an inability to cope with rigorous course loads (Cole & Espinoza, 2008; Goodman & Cunningham, 2002; Hutchinson-Green, Follman & Bodner, 2008). Some also perceive STEM classroom climates as "chilly", lacking community, or competitive, as evidenced by a "weeding out" process in introductory courses, in addition to perceptions that there is bias among STEM faculty (Atkinson, 2012; Cabrera, Colbeck & Terenzini, 2001; Cole & Espinoza, 2008; Diekman, Brown, Johnston, & Clark, 2010; Morris & Daniel, 2008; Moss-Racusin, Davidio, Brescoll, Graham & Handelsman, 2012).

Other factors are more specific to either gender or race/ethnicity. For instance, gender roles, bias, and/or stereotypes, whether explicit or implicit, in addition to concern for work-life balance issues, particularly those related to parenting, seem to be more of a factor influencing attrition in the STEM disciplines among women, particularly among White women (Dweck, 2006; Hill, Corbett, & St. Rose, 2010; Moss-Racusin et al., 2012). In contrast, socioeconomic status and ethnic/cultural identity seem to be factors influencing attrition in the STEM disciplines among URMs. These factors are closely identified with a lack of academic preparation, whether attributed to attitudes about education, inadequately prepared teachers resulting in poor educational quality in lower socioeconomic neighborhoods, lack of enrollment in Advance Placement courses, and/or lack of parental involvement/support (Anderson & Dongbin, 2006; Arcidiacono, Aucejo, & Hotz, 2013; Green & Glasson, 2009; Museus, Palmer, Davis & Maramba, 2011; Riegle-Crumb & Grodsky, 2010; National Academy of Sciences, et al, 2011). The lack of other-group orientation (comfort with intercultural interactions) also seems to be more of a factor for URMs (Byars-Winston, Estrada & Howard, 2008; Byars-Winston, Estrada, Howard, Davis, & Zalapa, 2010).

Inclusive excellence as approach to attrition in the STEM disciplines.

Many administrators and faculty at postsecondary institutions around the country (e.g., Georgia Tech, 2014; Hobart and William Smith Colleges, 2014; Rochester Institute of Technology, 2014; Saint Mary's College, 2014; Stetson University, 2014; The University of Arizona, 2014; University of Denver, 2014; University of New Hampshire, 2014; University of North Carolina Greensboro, 2014; Virginia Tech, 2014) articulate the need to address these various factors in terms of an emphasis on "inclusive excellence," a term promoted by the Association of American Colleges and Universities (AAC&U). Inclusive excellence is described as having four major emphases, including a focus on the intellectual and social development of students, purposeful development and utilization of organizational resources to enhance student learning, an awareness of students' cultural differences and how those differences benefit student learning, and a welcoming environment that "engages all of its diversity in the service of student and organizational learning" (Williams, Berger, & McClendon, 2005, vi).

The focus on inclusive excellence is a rejection of the "deficit" approach, which assumes, according to critics, that attrition is the result of the motivation and commitment that individual students have toward the STEM disciplines, both before and after enrolling in college (Harper, 2010; Irizarry, 2009). In deficit models, both Harper and Irizarry suggest that faculty and administrators are absolved from making changes to accommodate the needs of underrepresented students, as these students are thought to be influenced by negative attitudes in the community about the value of education in general, stereotypical images held by members of the community of who can and cannot achieve in rigorous disciplines such as the STEM disciplines, and by failing schools. Inclusive excellence, on the other hand, assumes that underrepresented students can and will rise to high expectations provided institutions have a better understanding of the conditions in which they thrive. This premise is central to this study.

Postsecondary Initiatives Targeting Women and URMs.

The wide range of initiatives designed to address the underrepresentation of women and minorities include those involved with increasing the number of women and URMs among the STEM faculty (Lechuga, 2012; Maton & Hrabowski, 2004; Xu & Martin, 2011); providing enhanced academic opportunities vs. remedial support for women and URMs (Alvarado & Dodds, 2010; Brigdall & Gordon, 2005; Gihiérrez, Morales & Martinez, 2009; Harper, 2010); introducing peer study groups (Brigdall & Gordon, 2005; Fullilove & Treisman, 1990; Powell, Murphy, Cannon, Gordon & Ramachandran, 2012); developing marketing strategies for making the STEM disciplines more attractive to women and URMs (Burke, 2007; Malcolm, 2008; O'Connell & Holmes, 2011; Rosser, 2003; Tillberg & McGrath, 2005); and enhancing teaching and learning in the STEM disciplines at the P-20 levels (Anderson et al, 2011; Elrod, 2010; Fairweather, 2010; Hora, 2013; Museus, Palmer, Davis & Maramaba, 2011; Office of the President, 2010; Ryan & DePillis, 2010). There is evidence to show that many of these initiatives are working, even if they do not have a broad enough reach to impact the graduation rates of women and URMs in the STEM disciplines.

Political climate around issues of inclusion.

Although there is increased support for developing programs that address the disproportionately low graduation rates of women and URMs in the STEM disciplines, this is now coupled with speculation about how the Supreme Court decision on June 24, 2013, will impact “race-based” or “race-conscious” admissions (Jaschik, 2013; Sacks & Reilly, 2013; Schwartz, 2013). Some are beginning to challenge programs designed specifically for any particular group of students at the exclusion of others (Kahlenberg, 2013; Sturm, 2006; Taylor, 2013). So, while on the surface agreement appears to exist about student groups that are underrepresented in STEM undergraduate degree programs and the negative outcomes associated with that underrepresentation, beneath the surface divisive disagreements are beginning to swell about how to tackle issues of inclusion and quality. In addition, increasing external pressure on postsecondary institutions to be more accountable to the general public is mounting (Conner & Rabovsky, 2011; Kallison & Cohen, 2010; Rabovsky, 2012) amidst increasing internal pressure to resist these intrusions on the “sacred” space of higher education (Giroux, 2002; Lincoln, 2011; Tuchman, 2011). All of these issues reveal why the achievements of the initiatives in the model departments and school are commendable, given the complex environment in which they were conceived.

Organization of the Study

To facilitate an understanding of how this study advances the literature, Chapter 2 will provide a review of the models that influenced the framework for this study, an overview of similar studies that have been conducted, and a discussion of barriers that institutions face when undergoing systemic change. Chapter 3 will then detail the methodology used to examine the strategies utilized among the model departments and school. To provide an in-depth analysis of the strategies, a chapter will be devoted to each department and school – Chapter 4 for the Department of Computer Science at HMC, Chapter 5 for the Department of Physics at MIT, and Chapter 6 for the Cockrell School of Engineering at UT-Austin. The following chapter, Chapter 7, will then provide a cross-case analysis to highlight differences and similarities of strategies across the three institutions. The final chapter will provide a discussion of the implications of the study and recommendations for future research.

CHAPTER 2
Literature Review

In her research, Holley (2009) noted that change efforts related to organizations have acquired numerous labels and descriptors, including transformational change, organizational change, strategic change, innovation, and adaptation, among others. In addition to the numerous labels associated with transformational change, the related literature is voluminous. Van de Ven and Poole (1995), as an example, conducted a "computerized literature search" across disciplines. "To our surprise," they noted, "more than 1 million articles have been published on the subject in the disciplines of psychology, sociology, education, business and economics, as well as biology, medicine, meteorology, and geography" (p. 512).

Within higher education, however, the literature on transformational change is scarce, which is a notable concern, since higher education contexts differ greatly from other contexts. Kezar (2001), for instance, noted thirteen aspects of higher education that differentiate it from other institutions. These "features" include interdependent organization, relative independence from external environment, uniqueness of culture in the academy, emphasis on institutional status, values-driven focus, multiple power and authority structures, loosely-coupled systems, organized anarchical decision-making, professional and administrative values, shared governance, employee commitment and tenure, goal-ambiguity, and emphasis on image and success (p. 61). These differences necessitate a review of change models developed within the context of higher education to ensure that adequate consideration is given to each of the "features" when considering strategies involved with transformational change.

Much of what is offered in the literature on organizational change in higher education contexts is comprised of models, theories, and anecdotal generalizations about strategies that can be utilized, depending on the circumstance, to assist with change efforts (Allen, 2003; Austin, Laursen, Hunter, Soto, & Martinez, 2011; Boyce, 2003; Gumpart, 2000; Kezar, 2001). Although scholars provide these as informative frameworks through which to approach transformational change, rarely do they provide empirical evidence that supports the use of such frameworks and strategies.

Notable exceptions include Kezar, Eckel and their colleagues, who have done extensive research on transformational change within the context of higher education environments (Eckel, Green, Hill & Mallon, 1999; Eckel, Hill & Green, 1998; Kezar, 2001; Kezar, 2009; Kezar & Eckel, 2002). Eckel, Hill, and Green (1998) suggested that transformational change "alters the culture of the institution by changing select underlying assumptions and institutional behaviors, processes, and products" in ways that are intentional, deep and pervasive throughout the institution, and staged over time (p. 3).

This concept of transformational change aligns well with this study's emphasis on inclusive excellence, which requires the institution to take responsibility for its role in addressing the issues that underrepresented student populations face (Williams, Berger, & McClendon, 2005, vi). This is in contrast to the more traditional or "deficit" approaches, which place the primary responsibility on students (Harper, 2010; Irizarry, 2009). Deficit approaches lend themselves to the types of programs that operate at the periphery of the department and thus do not require deviations from the status quo. An emphasis on inclusive excellence, in comparison, requires a total change or transformation in how members of the department/school think about and approach the issues that women and URMs face. This type of change makes it possible to implement programs on a scale large enough to significantly increase the numbers of women and URMs in disciplines such as computer science, physics, and engineering, as demonstrated by the model departments and school in this study.

Transformational Change Model for Inclusive Excellence

The Transformational Change Model for Inclusive Excellence (TCMIE), the conceptual framework developed for this study, details eight strategies for transforming the culture of an organization around issues of inclusion and excellence. These eight strategies include the following: 1) understanding and articulating the rationale for change, 2) securing buy-in and advocacy from senior leadership, 3) engaging in collaborative leadership at multiple levels, 4) developing a flexible vision; 5) providing ongoing professional development related to proposed changes, 6) emphasizing planned attention to the environment for underrepresented student populations, 7) engaging in high impact visible actions that are staged over time, and 8) conducting continuous assessment and evaluation. These strategies were adapted from the transformational change model, which outlines core strategies identified as instrumental in general transformational change efforts, from the social transformational theory of change, which describes processes specific to an effort within the STEM disciplines, and in consideration of the barriers that interfere with change efforts related to the STEM disciplines.

Transformational Change Model

Kezar and Eckel (2002) developed a framework for transformational change that they applied in a multiple case study of 26 higher education institutions participating in the American Council on Education (ACE) Project on Leadership and Institutional Transformation. The ACE Project offered funding to assist with the efforts of faculty, staff, and administrators who were engaging in transformational change around key issues that were pertinent to their respective campuses. By studying these institutions, Kezar and Eckel hoped to capture commonalities in the processes utilized at each of these institutions to achieve success with the various initiatives undertaken.

Teleological theory, the theory on which their study was based, was conceived by Van De Ven and Poole (1995) and drew from theorists associated with functionalism, decision-making, and strategic planning. This theory, predicated on the notion that institutions are purposeful and adaptive, suggested that the process of change involves goal-setting and strategic planning. Although noting that teleological theory is often criticized because of its linear approach to change, Kezar and Eckel (2002) felt that this theory was most useful in studying transformational change in higher education because it had been applied in empirical studies within higher education, it had proven helpful to practitioners, and because it offered change research from which to build.

Kezar and Eckel (2002) determined that the following major strategies, which were applications of teleological theory, could be tested to determine whether they had a role in driving the change process at the six institutions involved in their study: 1.) a willing president or strong administrative leadership, 2.) a collaborative process, 3.)

persuasive and effective communication, 4.) motivating vision and mission, 5.) long-term orientation, 6.) rewards or incentives, and 7.) supportive structures.

Kezar and Eckel (2002) used several data collection techniques at each of the institutions, including collecting internal institution documents; having participant-observers answer open-ended questionnaires and participate in project meetings; having experienced educational consultants participate in outside research teams to conduct interviews, attend meetings and events, and conduct informal observations; and having these outside research teams also interview key faculty, administrators, staff, and students. A thorough three-pronged approach to analysis of the data – categorical analysis, memoing, and narrative analysis – revealed three key findings from which Kezar and Eckel drew two conclusions.

Among their findings, they discovered that there were five core strategies for transformational change, two of which were not among the teleological strategies noted earlier: 1) senior administrative support, which surfaced as value statements, resources, or administrative structures; 2) collaborative leadership, which included "positional" and "nonpositional" individuals from across campus who were involved throughout the entire project; 3) robust design, which referred to creating a vision that was clear and understandable and creating clear goals and objectives to achieve the vision; 4) staff development, which involved providing training on issues related to the change effort; and 5) visible action, which consisted of visible and well-promoted activities that helped build momentum for the change effort (Kezar & Eckel, 2002, Appendix 2, p. 322-323).

In a second finding from the study, sensemaking emerged as a dominant theme in all but one of the aforementioned core strategies (Kezar & Eckel, 2002). According to Ancona (2002),

> [s]ensemaking involves coming up with a plausible understanding – a map – of a shifting world; testing this map with others through data collection, action, and conversation; and then refining, or abandoning, the map depending on how credible it is. Sensemaking enables leaders to have a better grasp of what is going on in their environments, thus facilitating other leadership activities such as visioning, relating, and inventing (p. 3).

According to Kezar and Eckel (2002), senior administrators in their study played an important role in the change process by creating an environment that supported sensemaking. From there, staff development, robust design, and collaborative leadership gave numerous opportunities for key participants, including critics, across levels and up and down the various hierarchies, to question the rationale for the proposed changes at their respective institutions, to make sense of the particular changes proposed, and to act based on their new understandings.

A third finding from Kezar and Eckel's study was that each of the five core strategies was linked to each other and to other secondary strategies. These strategies followed a clustering rather than linear pattern, and as a result, the leaders involved in the change processes were constantly balancing strategies in ways that were specific to institutional contexts.

Kezar and Eckel (2002) concluded that examining change through multiple theoretical lenses is central to understanding the change process and that the social cognition models with their attention to "ambiguity, struggle, and the individuality of the change process" (p. 319) should be incorporated into future research on transformational change, in addition to biological models that include consideration of balance in the change process. They also noted that the self-selection process of institutions participating in the ACE Project, the self-reporting of data by study participants potentially being biased toward success, and the incompleteness of the projects, which were only in the fourth year of a 5 ½-year process, were all limitations of the study.

This study by Kezar and Eckel, with its detailed attention to organizational processes in higher education, highly influenced the framework for this study, because it provided a starting point by which to consider how the change process unfolded within the model departments and school examined for this study. The strategies from the transformational change theory also prompted consideration of how these change processes might differ within the specific context of the STEM disciplines.

Social transformation theory of change.

Maton, Hrabowski, Özdemir, and Wimms (2008) proposed a social transformation theory of change that provided insight into transformational change processes within the STEM disciplines. Their theory emerged from a case study of the Meyerhoff Scholars program at the University of Maryland Baltimore County (UMBC), a program heralded nationally as a model for inclusive excellence in the STEM disciplines. The Meyerhoff Scholars program boasts high retention and graduation rates among minorities in the STEM disciplines, in addition to high graduation rates of URMs pursuing and obtaining doctoral degrees in the STEM disciplines.

To address the perception among African American faculty and students that UMBC had a negative racial climate, Dr. Freeman Hrabowski, then vice provost, initiated in the late 1980s what would become an institution-wide change effort (Maton, Pollard, McDoughall, Weise, & Hrabowksi, 2012). The president's council, under the direction of former president Dr. Michael Hooker, began by conducting a series of focus groups encouraging dialogue to understand the factors thought to contribute to these negative perceptions. These focus groups were followed by meetings among department chairs and faculty to discuss strategies for addressing the issues and concerns that surfaced during the focus groups.

The solutions addressed pedagogy and institutional climate and led to the funding and establishment of the Meyerhoff Scholars program in 1988. The "generous" support from Robert and Jane Meyerhoff allowed for the provision of financial assistance, mentoring, advising, and research experiences for African males, who initially were the main focus of the program (Maton, Pollard, McDoughall, Weise, & Hrabowksi, 2012, p. 5). Two years later, the program was expanded to include female students, and in 1996 it further expanded to include students of all backgrounds who were committed to increasing the representation of minorities in the STEM disciplines.

The success of the Meyerhoff Scholars program, according to Maton, Hrabowski, and their colleagues (2008), is directly related to having created empowering settings for minority students, having engaged in transformative institutional change that focused on inclusion and excellence, and having developed a culture of assessment and evaluation. These three elements comprise the strategies they proposed in the social transformation theory of change.

The first of these elements, empowering settings, is based on Maton's conception of empowerment, which he described as "a group-based, participatory developmental process through which marginalized or oppressed individuals and groups gain greater control over their lives and environment, acquire valued resources and basic rights, and achieve important life goals and reduced societal marginalization" (Maton, 2008, p.5). Maton further posited that there are four essential elements to establishing empowering settings for minority students: 1) a group-based belief system that is inspiring and strengths-based and that encourages an outlook that is not narrowly focused on self; 2) a pervasive, highly accessible, and multifunctional role structure in which students vacillate between learners and mentors in multiple settings that complement the academic program; 3) a multi-faceted support system that is encompassing of the holistic needs of the students, peer-based, and that provides a sense of community; and 4) empowering program leadership that is shared, inspirational, highly skilled, and committed to the students.

Maton, Hrabowski, and colleagues (2008) acknowledged the Inclusive Excellence and Change in Postsecondary Institutions model promoted by the American Association of Colleges and Universities when addressing the second element of their model, which pertains to a transformational change process. In the social transformation theory, Maton,Hrabowski and colleagues specifically noted elements of change referenced in the IECPI model that related to structural/bureaucratic, collegial, and symbolic dimensions of the organization, the most important of which was institutionalizing the commitment to inclusive excellence (Williams, Berger, & McClendon, 2005). This commitment led to the building of coalitions among key faculty and department chairs, without which according to Maton, Pollard, McDhougal, and Hrabowski (2012), “it is unlikely that institutional change would have followed” (p. 621). Maton and colleagues also noted that addressing the campus history of inequality was a key aspect of the symbolic dimension that allowed the campus community to “make sense of and rally behind the change process” (p. 621).

The final element of the social transformation theory of change relates to assessment and evaluation. Leadership in the Meyerhoff Scholars program relied on a data-driven approach to monitor progress and draw attention to areas of need. The areas within which data were collected at UMBC were consistent with those outlined in the IECPI model. Specifically, the concept of the inclusive excellence scorecard in the IECPI model, which builds on the research of Bensimon (2004), Hurtado (1999), Smith (1997), Gurin (2002) and each of their colleagues, involved an emphasis on institutional (or unit/departmental) evaluation or assessment in four major areas: access and equity, diversity in the formal and informal curriculum, campus climate, and student learning and development (Williams, Berger, & McClendon, 2005).

In addition to the areas outlined in the IECPI model, Maton, Hrabowski, and colleagues (2008) suggested that it was important to also assess student learning related to diversity and multiculturalism and to ensure that this assessment was geared toward all students, not just minority students. They also stressed the importance of consistently measuring the organizational characteristics of empowering settings, organizational behavior and culture, and the strategic change process.

Two of the limitations of the study that Maton and his colleagues (2012) acknowledged included the failure to assess “institution-level variables,” such as faculty buy-in and institutional culture change, and the inability to make generalizations about study findings due to the unique focus of the Meyerhoff program, the level of funding it received, and the level of commitment to the program by university administration, in particular, Dr. Hrabowski who is now president of UMBC (p. 621).

The emphasis on empowering settings and the detailed description of the process involved with collecting data about underrepresented populations were specific aspects of the social transformation theory of change that influenced the framework for this study.

Barriers to Transformational Change in the STEM Disciplines

With all the literature on promising practices in the STEM disciplines, it would seem that efforts to transform the STEM disciplines to reflect inclusive excellence would yield more promising results across the country. However, the literature reveals that there are numerous barriers to transformational change in the STEM disciplines that interfere with the implementation process as outlined by the framework for this study. Dancy and Henderson (2008) in their research on organizational change efforts with regard to faculty instruction stressed that it is important to document the barriers encountered during implementation efforts. "Although change agents are often aware of strong situational conditions that favor traditional instruction," according to them, "they often fail to document these barriers, mention the barriers in their dissemination efforts, or provide tools to help overcome the situational barrier" (p. 8). They further noted that "[a] greater emphasis needs to be placed on attempting to understand, classify, and change the situational characteristics that appear to play an important role in inhibiting changes in instructor practice" (p. 10). In much the same way, faculty, staff and administrators associated with transformational change efforts need to consider the barriers that might interfere with their change efforts.

Barriers to clear understanding and articulation of the rationale for change.

In the literature, scholars noted the debate surrounding institutional identity and mission as a barrier to efforts toward inclusion and excellence (Brophy, 2006; Kezar, 2009). Kezar (2009) described one such trend as "isomorphism." "In pursuit of prestige," she noted, "many institutions mimic their peers, which can be in direct conflict with the mission" (p. 22). She posited that this form of "keeping up with the Joneses" rather than understanding and articulating the specific circumstances that inform the rationale for change within the local change effort detract from the implementation process (p. 22).

Barriers to buy-in and advocacy from senior leadership.

Several scholars observed general lack of buy-in from university administrators, decision-makers, faculty, college departments, committees, and board members as barriers to transformational change (Hill et al, 2011; Sunal et al, 2011; Brophy, 2006; Kezar, 2009). Kezar (2009) implied that this lack of buy-in can be caused by senior administrators who fail to prioritize. "Once leaders get a handle on the change initiatives on a campus," she observed, "their range often makes priority-setting difficult…[t]he difficulty of doing this means that typically, no clear choices are made about what the campus will dedicate its finite human and financial resources to at any given time" (p. 20).

The failure to build capacity, an aspect of having senior buy-in, is mentioned in the literature in terms of employee turnover and ineffective hiring practices. As an example of employee turnover, even though presidents and administrative leaders may be among the few individuals who are aware of various change initiatives, suggested Kezar (2009), their terms of office are relatively short (p. 20). As a result, she noted, new presidents and administrators come into the office desiring to distinguish themselves from their predecessors by engaging in new initiatives rather than following through with previously started change initiatives.

> The tendency to start new initiatives rather than continue the implementation of existing ones needs to be addressed by trustees in particular. While some trustees look for leaders who will sustain existing efforts, the tendency is to look for visionary mavericks. We need instead to expect leaders to be both visionaries and implementers (p. 21).

With regard to hiring, Glass and Minnotte (2010) observed that "[e]ven when postings [for faculty positions] are done in non-traditional venues, employers still rely on existing intraorganizational networks to fill open positions" (p. 220). Their research further revealed that candidates who applied through these internal networks were more likely to be hired. This then undermined processes designed to attract qualified minority applicants who could serve as mentors and role models to underrepresented minorities enrolled in the STEM disciplines.

The inability to leverage resources, another aspect of senior buy-in, is often expressed in the literature in terms of time, incentives, and funding. Related to time, Hill and colleagues (2011) noted that faculty members and administrators needed more time to develop policies. Likewise, Dancy and Henderson (2008) noted the lack of instructor time to adapt new pedagogies in the STEM disciplines, especially considering the extent of content coverage expected by these innovations. At the same time, they disputed the notion that time is a necessary barrier.

> The argument that change is just slow and we should not expect large impacts from our change is problematic for several reasons. First, there are examples of sweeping change in education, such as the move toward high-stakes testing, which have not been slow. Under the right circumstances, change can and does take place much faster than the current change in STEM toward less lecture-based teaching (p. 11).

In addition to time, scholars also noted the lack of incentives from senior administrators as a barrier to leveraging resources that support inclusive excellence in the STEM disciplines. In research conducted by the American Association of Universities (2011), respondents felt their institutions valued research more than education. In a similar study, Seymore, De Welde, and Frye (2011) observed that all project directors "identified formal institutional rewards systems as the main structural deterrent to faculty who are otherwise disposed to revise their teaching" (p. 14). Kezar (2009) further observed that business has moved toward team-oriented reward structures, and, in her opinion, so should higher education. Similarly, Duderstadt (2008) suggested that a barrier to innovations in the engineering curriculum "is the dearth of rewards and recognition of achievements in this activity" (p. 65). Likewise, Brophy (2006) cited salary and equity concerns, and Sunal and colleagues (2001) cited tenure and promotion issues.

In terms of funding as an aspect of senior buy-in, Hill and colleagues (2011) suggested that barriers to successful change initiatives include declining financial support from state governments, the lack of institutional funding to improve faculty recruitment, the lack of competitive salaries and start-up packages in the STEM disciplines, and difficulties with spousal hire accommodations. Sunal and colleagues (2001) additionally pointed to changing institutions that are grappling with dwindling resources with regard to curriculum reform.

Barriers to collaborative leadership at multiple levels.

With regard to internal constituencies, Brophy (2006) noted campus politics, inability to work across divisions and departments, and institutional resistance to change as challenges to organizational change efforts. Additionally, Kezar (2009) observed that there is a lack of synergy among similar efforts and that this lack of synergy is related to a lack of information. She asserted that faculty and staff often have a narrow focus and do not contemplate how their initiatives might relate to others. As an example, she noted that the National Science Foundation or the National Institutes for Health may fund eight to ten different but related initiatives in the STEM disciplines at a particular institution, and those who are awarded may never work together or may not even know of each other's work. "This insularity," she added, "makes it difficult to create broader, more powerful movements for change" (p. 19).

Barriers to flexible vision.

In terms of the STEM curriculum as it relates to the environment and inclusive excellence, Duderstadt (2008) offered that status quo is frequently and strongly defended by the profession itself as the best option. "Engineers," she suggested, "are usually a conservative lot, frequently moored to the past, and will insist that the traditions of the engineering practice are not only well established but also time-tested and successful," ignoring what she described as the implications of engineering's increasingly globally competitive character (p. 65). This lack of flexibility, whether related to the curriculum in the STEM disciplines or other efforts, can stall efforts to initiate changes.

Barriers related to ongoing professional development.

Several scholars perceived the lack of training and ongoing professional development as a barrier to successful change efforts. Sunal et al. (2001), for example, posited that there is a lack of training and that curriculum materials are not readily available. Ebert-May and colleagues (2011) "posit[ed] that true understanding and implementation of learner-centered teaching cannot be taught without direct practice and feedback on that practice, which parallels how students learn" (p. 557).

Dancy and Henderson (2008) further noted curriculum-based STEM change strategies are primarily based on a development and dissemination model, as if awareness about curricular innovations is the only prerequisite for adaptation. This fails to take into consideration, they note, that some faculty feel that education research about new pedagogy in the STEM disciplines is too "dogmatic" and that a common sales pitch for new pedagogical techniques is that it will work in all environments. Additionally, they noted that the approach to sharing new innovations can put some faculty on the defensive, feeling as if they are bad instructors. Dancy and Henderson suggested that faculty feel a connection to their own personal styles and preferences and how that translates to their teaching practices. They offered that to counter these feelings, faculty must have a meaningful role in the change process and that this can be achieved by providing modifiable materials, focusing on the dissemination of research ideas in addition to related materials, and by conducting research on how well the pedagogies translate into different environments.

Barriers related to planned attention to the environment.

Several scholars have noted the pervasiveness of attitudes and behaviors in higher education and in the STEM disciplines, in particular, that run counter to how the environment is defined and/or envisioned (Brophy, 2006; Glass & Minnotte, 2010; Sunal, et al, 2001; Dancy & Henderson, 2008). Pertaining to faculty attitudes, Dancy and Henderson (2008) identified departmental norms as deterrents to inclusive excellence change initiatives. Likewise, Roos and Gatta (2009) pointed to their data, which suggested "the existence of subtle inequities that "arise in part from nonconscious attitudes and beliefs or organizationally based policies and procedures" (p. 196). These beliefs can impact how the environment is viewed by people external to the university. For instance, Hill and colleagues (2011) noted in their research that several minority candidates for faculty positions in the STEM disciplines were conscious of and concerned about regional stereotypes when making the decision to accept offers.

Barriers related to high impact visible actions that are staged over time.

Glass and Minnotte (2010) described an instance they discovered in their research in which the number of women faculty in science and engineering disciplines at a particular university decreased, in spite of efforts to encourage more hiring. According to them,

> evaluation revealed that awareness about change initiatives was generally low throughout the university, activities were limited only to women (not male faculty or students), there was little collaboration between the project and other university

offices, and focused professional development programs, such as mentoring and coaching were absent (p. 430).

In this case, lack of visibility presented itself as a barrier to effective implementation of change.

Hill and colleagues (2011) surmised that a barrier to successful implementation of change efforts is a failure to incorporate a plan for maintaining momentum throughout the organizational change process. Relatedly, Brophy (2006) suggested that some programs are developed and implemented at too quick a pace, resulting in "ambiguous" program development processes and cultures (p. 119). These types of barriers have potential to limit the impact of change initiatives.

Barriers related to continuous assessment and evaluation.

Often in the literature there is an assumption that strategies utilized to transform the culture of a department are effectively addressing the concerns expressed in the rationale for change. However, failure to assess and evaluate these strategies can impact successful implementation by masking weaknesses in the process. Ebert-May and colleagues (2011), for example, referenced workshops that had been conducted for faculty related to innovations in teaching. Follow-up with workshop participants revealed that "89% of faculty respondents whose teaching practices were videoed and analyzed stated that they made changes in their courses that included active, learner-centered instruction. Analysis revealed that 75% used lecture-based, teacher-centered pedagogy" (p. 554-555). In other words, faculty reported that they had made changes based on what they learned in the workshops, but their actual practice revealed that they were still primarily relying on lectures.

Conclusion

This study advances the literature by building on the organizational change models and theories in higher-education environments, addressing some of the limitations from prior studies in higher education and STEM discipline environments, and by addressing the barriers that can interfere with successful implementation of initiatives designed to increase the graduation rates of women and URMs in the STEM disciplines. The Transformational Change Model for Inclusive Excellence, the framework for this study, builds on the literature and provides practical guidelines for approaching major change initiatives within the STEM disciplines.

CHAPTER 3
Methodology

Overview of Study Questions

This study will address the following questions:

1) What strategies did faculty, staff, and administrators at each of the model institutions use to increase enrollment and graduation rates among women and/or underrepresented minorities (URMs) in their respective departments/schools?
2) In what sequence and to what extent were these strategies used to produce the desired changes?
3) What, if any, barriers did those responsible for implementing initiatives face, and what strategies did they use to overcome them?
4) How were the barriers and strategies similar and/or different across institutions?

Framework

The Transformational Change Model for Inclusive Excellence (TCMIE), the non-linear framework through which this study was approached, was adapted for this study from Kezar and Eckel's transformational change model (2002) and Maton and Hrabowski's social transformation theory of change model (2008). Based on these models and in consideration of the barriers that can sometimes interfere with change efforts, the TCMIE model offered eight major strategies that contribute to successful change initiatives in the STEM disciplines: 1) Understanding and articulation of the rationale for change, 2) buy-in and advocacy from senior leadership, 3) collaborative leadership at multiple levels, 4) flexible vision, 5) professional development in areas related to proposed change, 6) planned attention to environment for women and URMs, 7) high impact visible action that is staged over time, and 8) continuous assessment and evaluation. Figure 3.1 provides a visual representation of how the model was developed, and Table 3.1 provides a brief summary of the TCMIE model and its relationship to other models.

The literature shows that understanding the culture of an institution is an important aspect of being able to articulate the rationale for engaging in change initiatives related to inclusive excellence. Change agents must be able to conceptualize, quantitatively and qualitatively, how the environment influences inclusive excellence. Each of the models on which TCMIE is based underscores this importance (Kezar & Eckel, 2002; Maton, Hrabowski, Özdemir, & Wimms, 2008; Maton, Pollard, McDougall Weise & Hrabowski, 2012; Williams, Berger & McClendon, 2005). Being able to effectively articulate the rationale in clear and concise terms is an essential starting point from which to begin change efforts and one that may be revisited as often as necessary throughout the implementation process, particularly if circumstances change. Exemplary indicators of this strategy include evidence that the rationale is based on thorough research on internal and external factors that impact the graduation rates of women and URMs. Such evidence might be evident in, but not limited to, mission and goal statements, public statements from leaders associated with change efforts, and articles describing change initiatives.

The models from which the TCMIE was adapted also stress the importance of senior leadership buy-in and advocacy, especially since senior leaders often control the

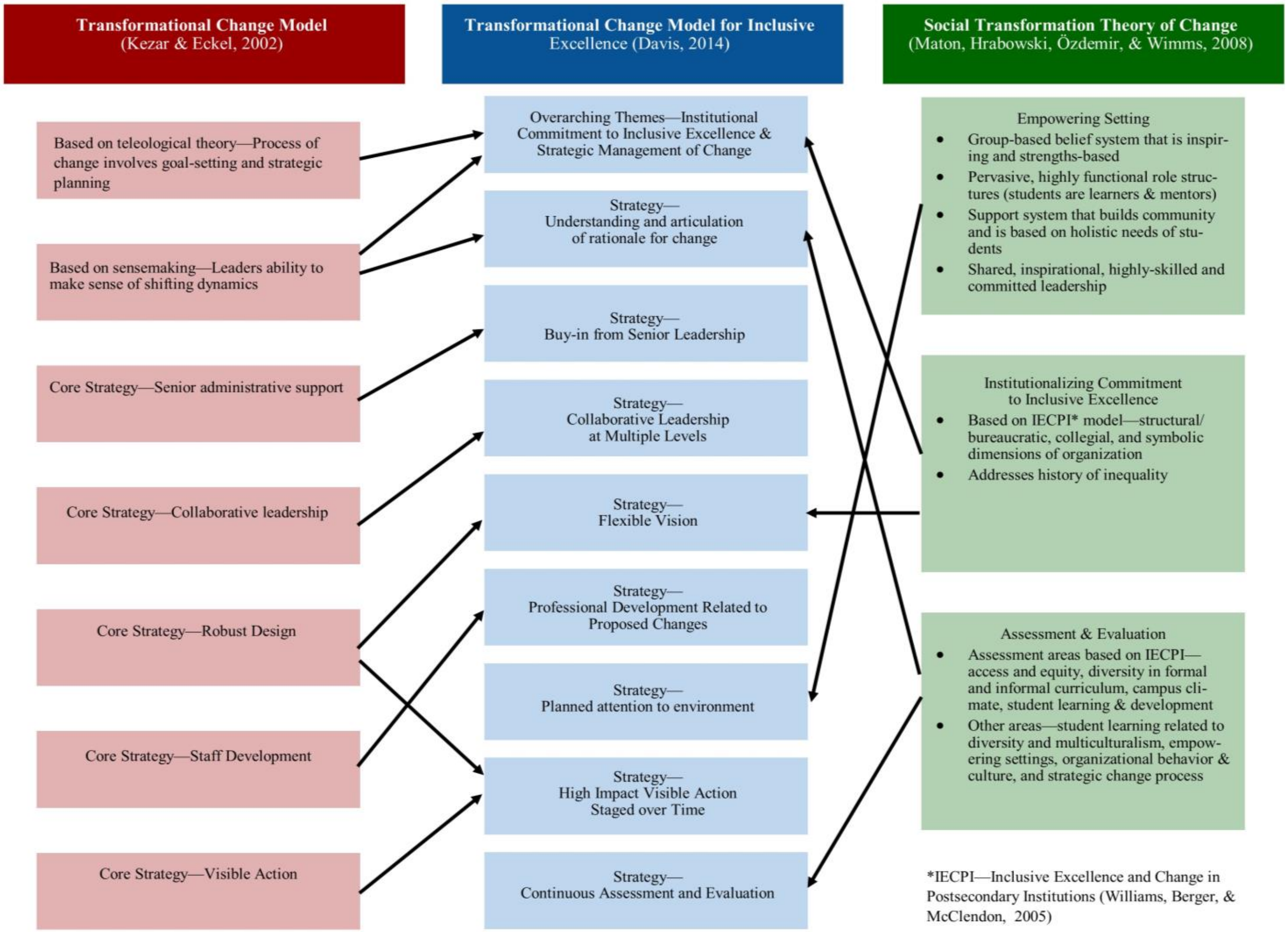

Figure 3.1 Diagram illustrating how the Transformational Change Model for Inclusive Excellence (TCMIE) was constructed.

Table 3.1

The Transformational Change Model for Inclusive Excellence

Strategies	Exemplary Indicators
Clear understanding and articulation of rationale for change	Evidence that rationale is based on thorough research on internal and external factors that impact the graduation rates of women and URMs—Such evidence might be evident in, but not limited to, mission and goal statements, public statements from leaders associated with change efforts, and articles describing change initiatives.
Buy-in and advocacy from senior leadership	• Evidence that senior leaders, in addition to providing vocal endorsement of change initiatives, provide assistance with regard to creating supportive structures (e.g., hiring practices, committee development, etc.) • Evidence that senior leaders allocate time, incentives, and funding
Collaborative leadership at multiple levels	Evidence of intentional attempts to include individuals who are from all levels of the organization and who will be impacted in some measure by the proposed changes in brainstorming and planning of initiatives and/or in providing feedback throughout the implementation process
Flexible vision	• Evidence of a plan or goal related to inclusive excellence • Evidence that plan is altered when conditions, such as those identified through assessment and evaluation, indicate a specific change or series of changes would better address the purpose as articulated in the rationale for the change
Professional development	Evidence of the identification of various avenues by which to promote awareness of change initiatives, such as, but not limited to, informational sessions at key times during the implementation process, workshops and training activities, and written or digital correspondence (e.g., letters from senior leaders, newsletters, social media posts, websites devoted to the change initiatives, etc.)
Planned attention to environment	• Evidence of a group-based belief system that is inspiring and strengths-based • Evidence of pervasive, highly functional role structures in which students vacillate between mentors and mentees • Evidence of a support system that builds community and is based on holistic needs of students • Evidence of shared leadership that is inspirational and highly-skilled
High impact visible action that is staged over time	• Evidence that faculty, staff, and administrators develop and implement initiatives designed to increase the enrollment and graduation rates of women and URMs • Evidence that faculty, staff, and administrators make far-reaching attempts to promote these activities to internal and external parties who might have responsibility for or the potential to be impacted by the initiatives • Evidence of planned activities designed to provide momentum for the initiatives (e.g., milestone celebrations, articles, informational meetings, etc.)
Continuous assessment and evaluation	Evidence of assessment and evaluation of access and equity, diversity in formal and informal curriculum, campus climate, student learning and development, student learning related to diversity and multiculturalism, empowering settings, organizational behavior and culture, and the strategic change process

Note. Adapted from "Examining the Institutional Transformation Process: The Importance of Sensemaking and Inter-Related Strategies" by A. Kezar and P. Eckel, 2002, *Research in Higher Education*, 43(3), p. 295-328, "Enhancing representation, retention and achievement of minority students in higher education: A social transformation theory of change" by K.I. Maton, F.A. Hrabowski, M. Özdemir, and H. Wimms, 2008, In Shinn, M., oshikawa, H.H. (eds.), *Toward Positive Youth Development: Transforming Schools and Community Programs*, and Toward a Model of Inclusive Excellence and Change in Postsecondary Institutions [White paper] by D.A. Williams, J.B. Berger, and S.A. McClendon, 2005, Retrieved from http://www.aacu.org/inclusive_excellence/documents/williams_et_al.pdf.

factors that contribute to an environment in which the change initiatives can prosper, such as the prioritization of initiatives, the development of staffing and committee structures, and the leveraging of resources (Kezar & Eckel, 2002; Williams, Berger & McClendon, 2005; Maton, Hrabowski, Özdemir, & Wimms, 2008). This buy-in may come at varying times during the change process, depending on the circumstances. Exemplary indicators of this strategy include evidence that senior leaders, in addition to providing vocal endorsement of the change initiatives, provide assistance with regard to creating supportive structures – e.g., prioritizing effective hiring practices to bring in talented individuals who can contribute expertise to planned initiatives and establishing effective committees to implement initiatives. In addition, there must also be evidence of support with regard to leveraging dedicated time for pursuing initiatives, employee incentives for participating in change efforts, and funding at the level required to ensure exemplary results. This strategy is key, as failure to attend to these issues is cited often in the literature as a barrier to successful implementation of promising initiatives.

Although senior leadership is important, each of the models on which the TCMIE is based suggest that collaborative leadership at many levels is also important to the success of change initiatives related to inclusive excellence. The IECPI model, as an example, asserts that various stakeholders must be empowered to brainstorm ideas for the ways that their particular units of the organization will respond to challenges they face in the areas of inclusive excellence (Williams, Berger, & McClendon, 2005) or in this case to challenges faculty, staff, and administrators face with regard to graduating women and URMs in disciplines such as computer science, physics, and engineering. It further notes that these challenges may be different from how other units within the organization experience challenges. Exemplary indicators of this strategy include evidence of intentional attempts to include individuals, who are from all levels of the organization and who will be impacted in some measure by the proposed changes, in brainstorming and planning of initiatives and/or in providing feedback on various aspects of proposed changes throughout the implementation process. These individuals may be internal or external to the department and/or campus community. Attention to this strategy has the potential to influence other strategies, such as buy-in from senior leadership and professional development related to proposed changes.

Flexible vision and professional development are other strategies identified in the literature as important to successful change efforts. It is key to develop a vision for change initiatives that is informed by the clearly articulated rationale mentioned earlier. However, this vision must be adaptable, allowing for the nuances and complexities associated with any organizational change effort and not a one-size-fits-all proposition (Bolman & Deal, 1991; Kezar & Eckel, 2002; Maton, Pollard, McDhougal & Hrabowski, 2012). Exemplary indicators of this strategy include evidence of a plan or goal related to inclusive excellence and evidence that this plan is altered when conditions, such as those identified through assessment and evaluation, indicate a specific change or series of changes would better address the purpose as articulated in the rationale for the change initiative.

To buy in to such a vision, faculty, staff, and administrators must be aware of the vision and activities associated with proposed initiatives and of the innovations in their respective fields that relate to the vision and goals toward which the institution is striving. In other words, there must be a commitment to ongoing professional development by faculty, administrators, and staff at multiple levels (Bolman & Deal, 1991; Kezar & Eckel, 2002; Maton, Pollard, McDhougal & Hrabowski, 2012). Exemplary indicators of this strategy include evidence of the identification of various avenues by which to promote awareness of change initiatives, such as, but not limited to, informational sessions at key times during the implementation process, workshops and training activities, and written and digital correspondence (e.g., letters from senior leaders, newsletters, social media posts, websites devoted to the change initiative, etc.). This strategy feeds into other strategies such as buy-in from senior leaders and high impact visible actions staged over time.

As noted in the literature, Maton, Hrabowski, and their colleagues (2008) suggested the importance of creating empowering settings for underrepresented students. In this study, planned attention to the environment for women and URMs involves fostering an environment in which these populations of students can thrive. Exemplary indicators of this strategy are based on Maton's conception of the conditions for developing empowering settings and include evidence of a group-based belief system that is inspiring, strengths-based, and focused on connectedness to the communities from which students come; a pervasive, highly accessible, and multifunctional role structure among initiatives in which students vacillate between learners and mentors in multiple settings that complement the academic program; a multi-faceted, peer-based support system that addresses the holistic needs of the students and that provides a sense of community; and empowering program leadership that is shared, inspirational, highly skilled, and committed to the students. This attention to the environment is responsive to the rationale articulated for proposed change initiatives and feeds into high impact visible actions staged over time.

Another key strategy for successful implementation of change efforts in the STEM disciplines is ensuring that actions related to change initiatives are highly visible. Actions or initiatives that are done in isolation, referred to earlier as "islands of innovation" (Clayton-Pedersen & Musil, 2005) often do not translate into systemic or transformative change and can in some cases deter from change efforts (Glass & Minnotte, 2010). Kezar & Eckel (2002) noted that it is equally important to stage actions over time based on what makes the most sense in the context of the organization in which the change is initiated. Relatedly, the literature on barriers to organizational change notes the importance of striking a balance between allowing sufficient time to gain buy-in through communication and professional development and seizing on the momentum of the initiative (Hill, Shaw, Taylor & Hallar, 2011; Kezar & Eckel, 2002). Beyond these strategies, it is also important that the initiatives in the STEM disciplines that are designed to broaden participation either individually or collectively have the potential to impact a large number of students from underrepresented populations. Exemplary indicators of this strategy include evidence that faculty, staff, and administrators develop and implement initiatives designed to increase the enrollment and graduation rates of women and URMs and that they make far-reaching attempts to promote initiatives to both internal and external parties who might have responsibility for or the potential to be impacted by the initiatives. In addition exemplary indicators include evidence of planned activities designed to provide momentum (e.g., milestone celebrations, articles, informational meetings, etc.).

Maton, Hrabowski, and their colleagues (2008), as well as other scholars, have noted that assessment and evaluation, which are described as data-driven approaches to monitoring progress and drawing attention to areas of need, are strategies that are often overlooked in the process of change (Bolman & Deal, 1991; Berger & McClendon, 2005; George-Jackson & Rincon, 2011). As noted in the literature, exemplary indicators for this strategy include evidence of assessment and evaluation of access and equity (e.g., the number of students from underrepresented populations in introductory courses, the number of faculty in the STEM disciplines who are from underrepresented populations, the number of women and URMs in honors courses, etc.), diversity in the formal and informal curriculum, campus climate, student learning outcomes, student development, student learning outcomes related to diversity and multiculturalism, empowering settings as outlined by Maton, organizational behavior and culture, and the extent to which the strategic change process is on track (Maton, Hrabowski, Özdemir, & Wimms, 2008; Williams, Berger, & McClendon, 2005). Attention to these areas ensures that visible actions are effectively addressing the circumstances that inform the rationale for change and that the implementation processes are effectively facilitating change efforts.

Each of the documents used as data in this study was analyzed, coded, and discussed in consideration of these eight strategies from the transformational change model for inclusive excellence.

Study Design

A multiple case study of undergraduate departments/colleges that have experienced success with increases in enrollment and graduation rates among women and/or URMs in the STEM fields in the last five to fifteen years was conducted to address these research questions. Qualitative research, specifically the case study method, lends itself to in-depth analysis of complex phenomena, such as the underrepresentation of women and minorities in the STEM; an understanding of processes through the lenses of those most associated with the processes; and the ability to analyze and compare data across cases (Glesne, 2011; Maxwell, 2005; Yin, 2003). As Yin (2003) noted, "the case study method allows investigators to retain the holistic and meaningful characteristics of real-life events – such as individual life cycles, organizational and managerial processes" (p. 2).

Content analysis approach.

The specific approach to analysis in this study was qualitative content analysis. Elo & Kyngäs (2008), referencing Krippendorff (1980), described content analysis as "a research method for making replicable and valid inferences from data to their context, with the purpose of providing knowledge, new insights, a representation of facts and a practical guide to action" (p. 108). Originating in the 19th century as a method for analyzing hymns, news articles, and political speeches, this technique is now utilized for research in a variety of fields, including, marketing and media studies, ethnographic and cultural studies, sociology, political science, psychology, and cognitive science (Elo & Kyngäs, 2008; Krippendorff, 2013).

There were several advantages to content analysis as an approach for this study. Among them was the fact that content analysis facilitated the incorporation of large amounts of data from different contexts, making it possible to track trends and patterns from the perspectives of a variety of individuals, groups, and institutions, which contributed to more robust findings (Krippendorrff, 2013; Stemler, 2001).

In addition, content analysis is an unobtrusive technique. Other "acts of measurement," such as interviews, focus groups, surveys, and controlled experiments, "interfere with the phenomena being assessed and create contaminated observations" (Krippendorff, 2013, p. 45). A GAO (1996) report explained how that is so.

> One problem with surveys and some experimental methods is that evaluators and their informants can interact during data collection in ways other than how they would "naturally" react…[they] might leave out important points, unconsciously or purposely, in order to protect themselves (p. 9).

Although some of these other methods, specifically interviews and member checking, were used for triangulation in this study, some of the accounts of how certain events transpired were in conflict with those of historical documents. For instance, one participant indicated that a particular program had been around for over 20 years. Several historical documents retrieved from multiple sources, however, revealed that this was not the case.

As Stemler (2001) noted, another advantage of the content analysis approach is that it allows inferences to be made, which can later be corroborated using other methods of data collection. In this study, the researcher was able to follow up on particular events or trends with study participants that would not have been addressed through the prepared interview protocol.

To conduct content analysis, different types of documents were collected, including departmental/school information on the college or university web site; federal and private grant documents; departmental agendas, announcements, minutes, reports, and other similar information; formal evaluation records; scholarly literature; and mass media articles, photos and documents, as well as transcripts from video interviews. Most of these documents were publicly-available documents that were obtained from the internet. Other documents were requested from faculty and/or administrators in each of the model departments and school. Each document and interview transcript was assigned an ID to distinguish it as part of a data set, as opposed to part of the reference list for the study. The first three letters of the ID were abbreviations of the institutions (HMC, MIT, UTA). The number in the middle, separated by hyphens is an indication of where the document may be located on the list of collected documents for the institutions, and the next letter(s), separated by a hyphen, indicated the type of document, such as whether the document was a journal article, institutional report, or an interview transcript. This ID is referenced in the findings section for each department and school. Appendix A provides the complete listing of documents from each case by ID.

Interviews.

In addition to gathering documents, eight semi-structured phone interviews were conducted with faculty and administrators – two at HMC, three at MIT, and three at UT-Austin –who had direct knowledge of the changes that occurred at each institution and/or familiarity with the current status of various initiatives. These faculty and administrators, identified through a preliminary review of the documents, were contacted via email and invited to participate in the study. Attached to the invitation for participation was a copy of the IRB approval letter for the study. In cases where there was no response after one week, a second notice was sent. When individuals agreed to participate in the study, a follow-up email was sent to coordinate interview times. Out of 15 people notified, 10 responded. Two of these indicated that they did not have direct knowledge of the initiatives within the respective departments/school, but each referred the researcher to others with more knowledge. One such interaction yielded an interview with a key informant.

All interviews, which were conducted within a span of three weeks, began with a scripted overview of the study, after which each person granted permission for the interview to be taped.   The interview protocol was used as a guide, but questions were also tailored to each participant based on the gaps in the documents collected from the individual's respective department/school.   At the end of each interview, each participant was asked for documents that would corroborate the information she/he shared during the interview, for additional study participant recommendations, for feedback on the interview transcripts, and for permission to contact her/him again to share preliminary findings. Each taped interview was transcribed by the researcher and emailed to the respective participants within one business day. Appendix B includes a copy of the participant invitation letter, the IRB approval letter, interview participant information, and the interview consent script/interview protocol.

Coding and analysis.

Following the procedures that Elo & Kyngäs outlined, a deductive and inductive process for coding the data was used. Berg (2008) described the deductive process as one in which the researcher already has "some categorical scheme suggested by a theoretical perspective, and the documents provide a means for assessing the hypothesis" (p. 246). As a first step to coding the data, this study included an exploration of themes related to the eight strategies that comprise the TCMIE, the framework guiding this study. The next step in the coding process included an inductive process, which was described by

Berg as one in which the researcher is open to the “themes that seem meaningful to the producers of each message [document]” that are not necessarily tied to any particular framework, a grounded theory of sorts (p. 245). Through this inductive process a second round of coding was conducted to capture themes that did not relate to the TCMIE. This was to allow for a deeper understanding of all the strategies that contributed to the success of each model department/school. This process is summarized in Figure 3.1. Once the data were coded and key quotations and summaries highlighted, the first level of coding for each model department/school was analyzed to determine the extent to which the strategies were portrayed as integral to the success of the change initiatives in the model departments and school. The next level of coding was then analyzed to determine whether there were recurring themes in the documents and whether these themes were also portrayed as integral to the success of the change initiatives in the model departments and school. An additional step incorporated comparative analysis across cases.

Sample selection.

Extreme sampling, a form of purposeful sampling, was utilized to identify the three “model” institutions for this study. Extreme sampling, according to Patton (2002), focuses specifically on characteristics in the sample that are “unusual or special in some way, such as outstanding successes or notable failures" (p. 231). The focus of this research was on undergraduate academic departments at four-year, Predominantly White Institutions (PWIs) that have achieved success with enrolling and graduating women and URMs in the STEM disciplines at higher percentages than the national average. PWI’s were selected since the literature shows that many women’s colleges and minority-

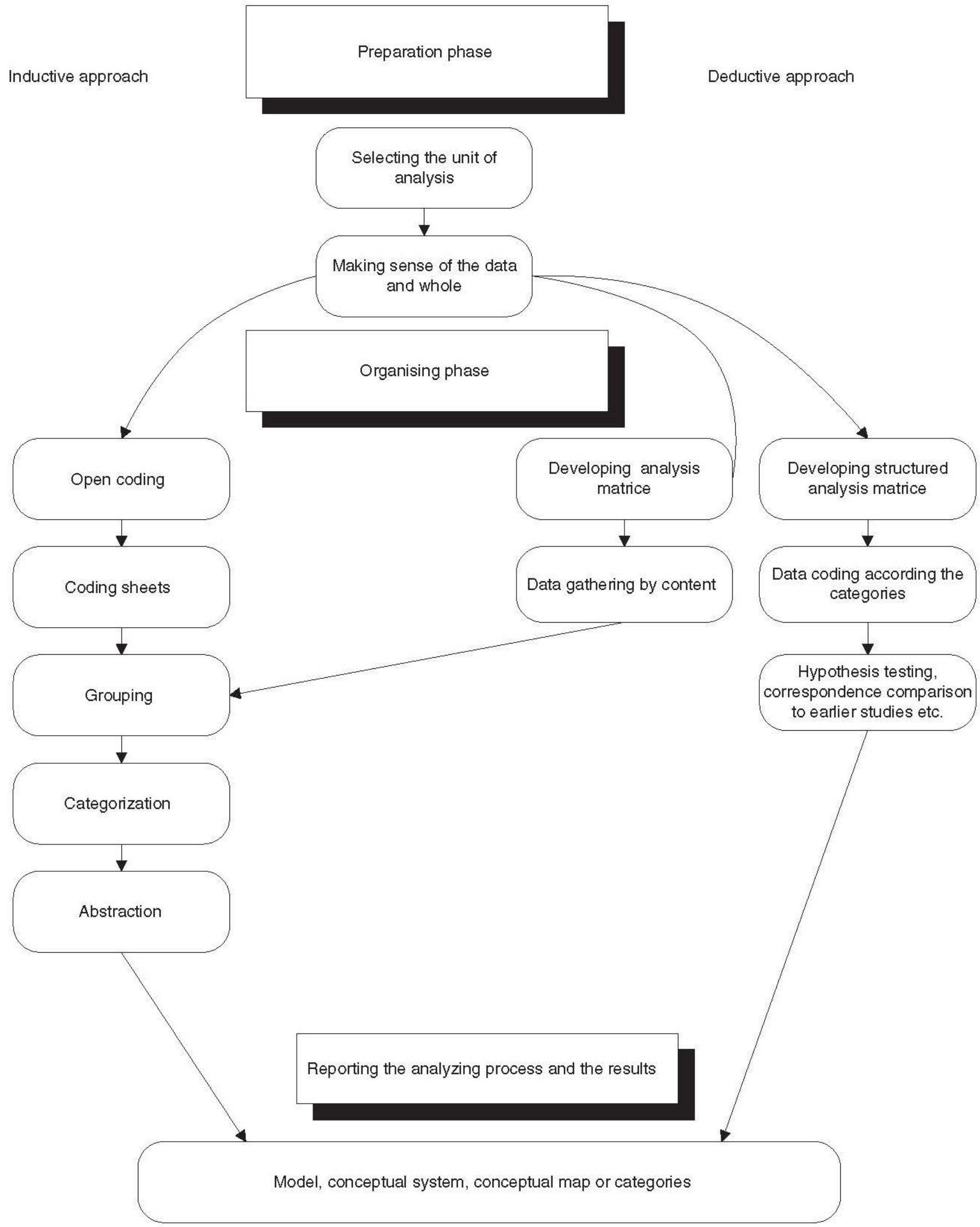

Figure 3.2 Flow chart of the preparation, organizing, and resulting phases in the content analysis process. Adapted from "The Qualitative Content Analysis Process," by S. Elo and H. Kyngäs, 2007, Journal of Advanced Nursing*, 62(1), 107-115.*

Given the underrepresentation of women and minorities in the STEM, particularly at PWI's, it is important to understand how model academic departments have had success, in case there are ways to cultivate similar environments at other PWIs. This is consistent with Patton's assertion about the logic of using extreme case sampling, which is that it facilitates learning about "unusual conditions or extreme outcomes that are relevant to improving more typical programs" (p. 232).

Multiple sources were used to identify "successful" academic departments, including the *Forbes* list of the best schools for women and minorities in the STEM (Doss, 2010); "Engineering by the Numbers," a publication of The American Society for Engineering Education (ASEE) (Yoder, 2012); the NSF's list of top 20 academic institutions awarding science and engineering bachelor's degrees from 2006 to 2012 by race/ethnicity of graduates (NSF, 2014, Table 5-12); and the top STEM degree producers as ranked by *Diverse Issues in Higher Education* (2013) in its analysis of U.S. Department of Education statistics. Online searches of STEM departments at each of the universities on each of these lists were conducted, excluding all those that were women's colleges or minority-serving institutions. From there, three criteria were used to identify the model institutions for this study.

Intentionality.

Each academic department had to have articulated an intentional plan to address diversity. In other words, there had to be some evidence that the academic department identified underrepresentation of women and/or minorities as a problem that needed to be addressed and that the department engaged in an effort to rectify the problem.

Timing of institutional change.

Institutions that initiated change efforts between 1998 and 2008 were used since much of the emphasis in the literature is on programs, such as the Meyerhoff Scholars program and Uri Treisman's Mathematics Workshop program (Virginia Community College System, 2011), which have been in existence for nearly three decades. In addition to focusing on more recent initiatives, it was also important not to select initiatives after 2008, as the literature reveals that sustainable change initiatives in higher education generally occur over time (Eckel, Hill, & Green, 1998; Kezar, 2009;).

Commitment to excellence.

Beyond graduation rates, evidence that the academic departments could demonstrate that women and/or URMs were achieving excellence as demonstrated by outstanding grades, extraordinary research experiences and awards, and/or high graduate school or career placement rates was a consideration in the selection criteria.

Construct Validity.

Triangulation, using multiple sources of data (Glesne, 2011), according to Yin (2003), increases construct validity by encouraging "convergent lines of inquiry" and by establishing a chain of evidence (p. 36). To further ensure construct validity, key informants were interviewed and invited to review findings, as suggested by Yin (p. 36) in a process Glesne refers to as member checking (2011).

Internal and External Validity.

To address internal validity in this study, the data analysis involved explanation-building, pattern-matching, and addressing rival explanations as suggested by Yin (2003). Explanation-building, according to Yin, is an iterative process that involves making an argument about observed behavior, comparing the findings of a case against the argument, revising the argument as deemed necessary, comparing the revision to the facts of other cases, and repeating this process as often as needed to make conclusions (p. 121-122). In this study, for instance, it was important to determine whether the conclusions made from one document matched those of subsequent documents. Similarly, Yin noted that pattern matching entails comparing an empirically based pattern with a predicted or alternative explanation (p. 116), which is consistent with this study's deductive and inductive coding approach. In this study, it was important to note the observations that aligned with the model, as well those that were unrelated.

As for external validity, Yin (2003) asserted that quantitative research focuses on statistical generalization, whereas qualitative research focuses on analytical generalization (p. 37). A strategy for external validity for this study included a cross-case synthesis, which Yin noted contributes to more robust findings (p. 133).

Subjectivity and Positionality.

Glesne (2011) noted that reflexivity, "critical reflection on how researcher, research participants, setting, and research procedures interact and influence each other" (p. 151), is often used as a means for making qualitative research more accurate or valid. She acknowledged that postmodern qualitative researchers might disagree with the notion of validity and qualitative research since a person can never know her/himself enough to provide a full critique. Regardless, she and others note that an awareness of one's subjectivity and positionality, although viewed negatively by some scholars, can prove helpful to the qualitative researcher (Drapeau, 2002; Glesne, 2011; Peshkin, 1998).

Drapeau, for instance, made reference to Perry's (1990) assertions that one's subjectivity makes one particularly vulnerable to certain defense mechanisms, such as denial, repression, displacement, or abstract/generalized thinking, which manifest themselves through such actions as overlooking certain data and meanings, overanalyzing others, forgetting certain major or minor concepts, and/or projecting one's feelings, thoughts, or impulses onto others (p. 17, 19, & 31). For this reason, triangulation, peer review, and other strategies mentioned earlier were critical to the validity of this study.

Reliability.

According to Yin (2003), the goal of reliability is to minimize error and bias in the study by ensuring that another researcher could follow the same procedures utilizing the same case and arrive at the same results (p. 37). Many of the strategies used to address construct validity, such as triangulation, member checking, and incorporating a multi-case design, also address reliability. In addition, utilizing Microsoft Excel software to assist with data analysis was also instrumental in creating an audit trail that contributed to the trustworthiness of the findings.

Study Limitations.

Although there were several advantages to the study design, there were also limitations. Krippendorf (2013) explained that researchers using this approach must manage text in various formats and created for different purposes, which can at times make it difficult to make sense of the contexts and purposes for which the content was intended, as well as to uncover the particular data related to the phenomena being studied. In addition, Berg (2008) noted that the collection of data in this approach is limited to content that has already been recorded, which does not allow for any interaction with the data to probe deeper. Each of these limitations was a factor in this study. Having multiple documents from different perspectives helped to minimize this limitation, as did interviewing key informants to get their perspectives.

Although this study addressed the limitations of prior higher education studies on organizational change (those utilizing content analysis) by using semi-structured interviews and member-checking, an additional measure to contribute to the robustness of the findings would have been to conduct observations at the sites of each of the model departments and school. This is recommended for future research.

As much as the collection of documents was helpful in this study, there were gaps in documentation. The study would have benefited from access to more of the actual planning documents, as opposed to documents that featured reflections on the implementation process. Surprisingly, faculty, staff, and administrators at the institutions were not forthcoming about providing that information, and they did not choose to disclose why. Perhaps it was because the discussions around diversity and inclusion if captured in planning documents can be misconstrued if not understood in the proper context, making participants hesitant to provide the information. Several of the participants hinted at this in expressing their concern for anonymity. Also related to gaps in the literature, it was difficult at times to separate actions that were part of the planned initiatives in this study from those that were part of other initiatives that were developed in advance of these programs.

Access to more of the individuals associated with the study would also have contributed to more robust findings. Everyone who was contacted did not agree to participate in the study; several people did not respond to invitations, even after being contacted multiple times. Perhaps this was because the timing of the interviews was not ideal, since prospective participants were contacted at the end of the spring semester, as faculty were grading final exams and other parties were preparing for year-end events such as graduation. Regarding the phone interviews that were conducted with those who did agree to participate, there is no way to determine what, if anything, was lost from conducting the interviews over the phone rather than in person.

Additionally, it is generally understood that the findings of qualitative studies, as discussed earlier, are not generalizable externally as in quantitative studies. Even though there are various ways to generate plausibility as indicated in this study design, it is understood, as Maxell (2005) noted, that "these characteristics can provide credibility to generalizations from qualitative studies, but none permits the kinds of precise extrapolation of results to defined populations that probability sampling allows" (p. 116). Even so, Maxwell and other scholars note that it is this limitation that is, in fact, a strength of qualitative research, as it allows for describing complex phenomena, lends itself well to studying a limited number of cases in-depth, provides understanding and description of the ways that individuals make meaning of their circumstances, and allows for an understanding of various processes that would not be as easy to capture with statistical analysis, among other strengths (Glesne, 2011; Maxwell, 2005; Yin, 2003). This was especially the case in this rich, in-depth study of the process of change from various perspectives of those external and internal to the model departments and school, particularly as it related to the divisive, complex, and exacting phenomenon of the underrepresentation of women and minorities in the STEM disciplines.

CHAPTER 4
Harvey Mudd College – Department Of Computer Science

The success of our efforts with women in CS demonstrates one of the ways Harvey Mudd College is transforming STEM education by creating and implementing truly innovative teaching and learning practices. We are passionate about making STEM education a vibrant, discovery-based, interdisciplinary experience that will excite and attract students and prepare these future scientists and engineers to take on the next generation of challenges. – Maria Klawe, President of Harvey Mudd College (Klawe, 2011)

College Profile

Harvey Mudd College (HMC), located in Claremont, California, is ranked number 4 on the *Forbes* list of best colleges for women in STEM disciplines (Doss, 2010). It is one of the seven independent higher education institutions with adjoining campuses – five undergraduate and two graduate institutions - in a consortium known as "The Claremont Colleges" (The Claremont Colleges, 2014). Chartered in 1955 and opened in 1957, HMC offers nine engineering, science, and mathematics-based majors grounded in the core curriculum of humanities and social science courses. Promoted as "one of the premier engineering, science and mathematics colleges in the nation" (Harvey Mudd College, 2014a), it has the unique distinction of also being classified as a liberal arts college. Initiated in 1963, another distinction of the College is its Clinic Program, a program in which students are tasked with solving problems posed by sponsoring industry, government, and non-profit organizations (Harvey Mudd College, 2014b). In addition, all students at the college take core first-year courses that are designed to give them exposure to the various disciplines offered at the college. Students then declare a major in their sophomore year.

During the 2013-2014 academic year, HMC, a diverse community and residential campus, enrolled nearly 800 students from 48 states and 26 foreign countries. In terms of ethnic diversity, 54 percent of its students were White, 22 percent Asian American/Asian, 11 percent minority, 8 percent international, and 5 percent classified as not having indicated an ethnicity. Additionally, 42 percent of the student population was female. With a freshman acceptance rate of 18 percent, 96.6 percent of these students ranked in the top ten percent of their high school classes and 33 percent were valedictorians or salutatorians of their high school classes. In addition, accepted students scored above 670 on all areas of the SAT, with highest scores in math. Following graduation, nearly 40 percent of students went on to graduate school, and nearly 60 percent went directly into the workforce with average starting salaries of $75,000 to $80,000 (HMC, 2014c).

The College employed 89 tenured or tenure-track faculty during the 2012-2013 academic year, 36 percent of which were female faculty, which allowed for a student-to-faculty ratio of 9 to 1. All faculty members held a Ph.D. or the highest degree in their respective fields. In addition, the faculty at HMC were the recipients of numerous awards, including, among others, the National Academy of Engineering's 2012 Bernard M. Gordon Prize for innovation in engineering and technology education; four Mathematical Association of America Alder Awards for distinguished teaching by a beginning faculty member; three NSF Career Awards recognizing extraordinary faculty in early stages of their careers for faculty in the biology, chemistry and computer science departments; and four Henry Dreyfus Teacher–Scholars in Chemistry, based on accomplishment in scholarly research with undergraduates and a compelling commitment to teaching (Harvey Mudd College, 2014c).

With tuition at $46,234 and room and board at $15,151, nearly 80 percent of students at HMC received financial aid up to $43,821. The College had an annual operating budget of $52 million in 2011-2012 and an endowment of $241 million as of June 30, 2013 (Harvey Mudd College, 2014c). Table 4.1 provides a brief summary profile of HMC.

Table 4.1

Harvey Mudd College Brief Profile: 2013-2014

Area of Interest	Description
Total Enrollment:	Nearly 800
Gender Ratio:	42 percent female, 58 percent male
Ethnic Distribution (10/2012):	White – 54 percent Asian American/Asian – 22 percent International – 8 percent Latino – 7 percent Unknown – 5 percent Multiracial – 2 percent African American – 1 percent American Indian/Alaska Native - <1 percent
Student Distribution:	48 states and 26 foreign countries
Admissions Acceptance Rate:	643 out of 3,540 (18 percent)
Freshman Class:	96.6 percent in top 10 percent of class 33 percent valedictorians or salutatorians
Freshman SAT Scores:	SAT 1 Critical Reading – 680-760 SAT 1 Math – 720-800 SAT 1 Writing – 670-760 SAT 2 Math 2 – 760-800
Freshman ACT Composite	32-35
Student-to-faculty ratio:	9:1
Students living on campus:	99 percent
Faculty	89 tenured or tenure track; all hold Ph.D. or highest degree in field
Faculty gender ration:	36 percent female, 64 percent male
Tuition:	$46,234
Room and board:	$15,151
Financial Aid	Nearly 80 percent of students receive financial aid up to $43,821
Placement in Graduate or Professional School:	Nearly 40 percent
Placement in Workforce:	Nearly 60 percent
Average starting salary:	$75,000 - $80,000
Endowment:	$241 million as of June 30, 2013
Annual operating budget:	$52 million (2011-2012)

Note. Adapted from "Harvey Mudd College: Fast Facts," Harvey Mudd College, Retrieved from www.hmc.edu/about-hmc/fast-facts/ and *IPEDS Data Center*, National Center for Education Statistics, Retrieved from http://nces.ed.gov/ipeds/datacenter/

Department of Computer Science Profile

The computer science (CS) department at HMC, formed in 1992, is a relatively new department at the College. Even so, it boasted the second and fourth most popular majors at HMC during the 2012-2013 academic year – computer science (22 percent) and computer science and mathematics (10.1 percent), respectively - behind engineering (33.7%), which was the most popular major (Harvey Mudd College, 2014c). In addition to those majors, the department, in conjunction with the biology department, also offers a degree in mathematical and computational biology. The CS department is comprised of ten tenured or tenure-track faculty members, two visiting professors, one adjunct faculty member, and three staff members, for a total of 16 faculty and staff members, which places it below the average number of faculty staff of all departments (HMC, Department of Computer Science, 2014). Table 4.2 provides more information about the computer science department as it compared to other departments at HMC in the 2012-2013 academic year.

Since the 2005-2006 academic year, the department has seen the most growth in the number of females who enrolled in and graduated with degrees in computer science. During the 2005-2006 academic year, 11.5 percent of the computer science graduates (three out of 26) were female students. Subsequently, by the 2011-2012 academic year, the number of female computer science graduates increased to 40.6 percent (thirteen out of 32). The department has not had as much success with underrepresented minorities, although it averaged two degree completions from Hispanic/Latino students each year (NCES, 2014). Table 4.3, Figure 4.1, and Figure 4.2 provide additional information about degree completions in the computer science department by gender and ethnicity.

Table 4.2

Brief Overview of Departments at HMC: 2013-2014

Department	Number of Faculty and Staff	Majors	Percent Distribution of Students
Biology	9 TT[a] Faculty 1 Emeritus Faculty 4 Staff Members 14 Total	Biology	1.3
Chemistry	12 TT[a] Faculty 2 Emeriti Faculty 1 Visiting Faculty 16 Total	Chemistry Chemistry and Biology	4.7 2.1
Computer Science	10 TT[a] Faculty 2 Visiting Faculty 1 Adjunct Faculty 3 Staff Members 16 Total	Computer Science Computer Science & Mathematics	22.0 10.1
Engineering	18 TT[a] Faculty 1 Visiting Faculty 1 Clinical Faculty 9 Emeriti Faculty 6 Staff Members 35 Total	Engineering	33.7
Humanities, Social Sciences, & the Arts	17 TT[a] Faculty 1 Visiting Faculty 3 Emeriti Faculty 21 Total	N/A	N/A
Mathematics	15 TT[a] Faculty 1 Adjunct Faculty 1 Teaching Fellow 3 Staff Members 21 Total	Mathematics Mathematical & Computational Biology Mathematical Biology (Discontinued)	8.5 4.0 0.3
Physics	12 TT[a] Faculty 3 Visiting Faculty 4 Staff Members 19 Tot	Physics	10.6

Note. Adapted from Departmental Websites on the Harvey Mudd College Website and IPEDS Data Center, National Center for Education Statistics, Retrieved from http://nces.edu.gov/ipeds/datacenter/

[a]TT – Tenure-Track

Table 4.3

Computer Science Degree Completions by Gender and Ethnicity

	2005-2006		2006-2007		2007-2008		2008-2009		2009-2010		2010-2011		2011-2012	
	#	%	#	%	#	%	#	%	#	%	#	%	#	%
Male	23	88.5	17	94.4	19	86.4	21	91.3	15	75.0	13	59.1	19	59.4
Female	3	11.5	1	5.5	3	13.7	2	8.7	5	25.0	9	40.9	13	40.6
AIAN	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Asian	1	3.9	2	11.1	3	13.7	1	4.3	3	15.0	3	13.6	3	9.4
BAA	0	0.0	1	5.5	0	0.0	1	4.3	0	0.0	0	0.0	1	6.3
H/L	2	7.7	0	0.0	2	9.1	2	8.7	4	20.0	2	9.1	1	6.3
NHOPI*	-	-	-	-	-	-	-	-	-	-	0	0.0	0	0.0
NRA	1	3.9	0	0.0	0	0.0	1	4.3	0	0.0	1	4.5	4	12.5
RU	6	23.1	6	33.3	5	22.7	3	13.0	4	20.0	1	4.5	0	0.0
TMR*	-	-	-	-	-	-	-	-	-	-	1	4.5	0	0.0
White	16	61.5	9	50.0	12	54.5	15	65.2	9	45.0	14	63.6	23	71.9

Note. Bold line indicated the year of the first graduating class since the three initiatives began in 2006. AIAN = American Indian/Alaska Native. BAA = Black/African American. H/L = Hispanic/Latino. NHOPI = Native Hawaiian or Other Pacific Islander. NRA = Non-Resident Alien. RU = Race Unknown. TMR = Two or More Races. NCES did not separate out NHOPI and TMR prior to 2010-2011. Adapted from IPEDS Data Center, National Center for Education Statistics, Retrieved from http://nces.ed.gov/ipeds/datacenter.

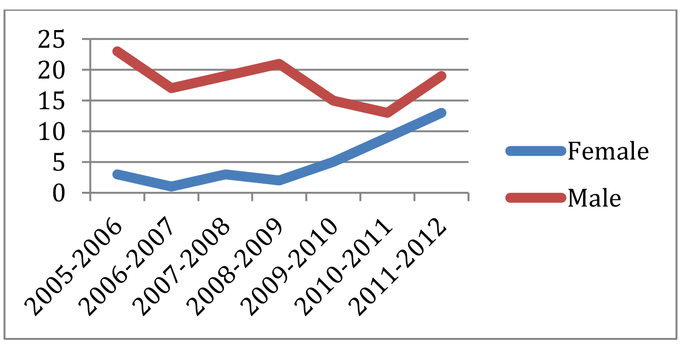

Figure 4.1 Chart illustrating computer science degree completions at HMC by gender. Adapted from IPEDS Data Center, National Center for Education Statistics (http://nces.ed.gov/ ipeds/datacenter/).

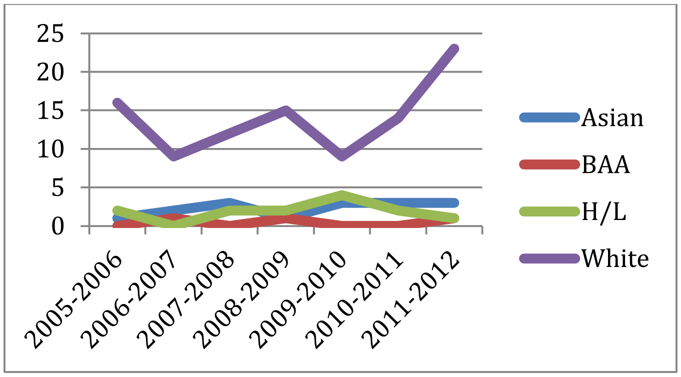

Figure 4.2 Chart illustrating computer science degree completions at HMC by ethnicity. Adapted from IPEDS Data Center, National Center for Education Statistics (http://nces.ed.gov/ ipeds/datacenter/).

After graduation approximately 80 percent of computer science majors have gone directly to work at places such as Microsoft, Google, LinkedIn, Amazon, Laserfiche, JP Morgan, Pivotal Labs, Twitter, Blizzard Entertainment, among others, and 20 percent have gone on to graduate schools at institutions such as the University of Washington, Carnegie Mellon University, University of California (UC) Berkeley, University of California Irvine, Massachusetts Institute of Technology, Cornell University, University of Texas Austin, and University of Oregon, among others (Harvey Mudd College, 2014c).

Document Collection Overview

To facilitate an understanding of the strategies that faculty and administrators utilized to transform the culture within the computer science department at Harvey Mudd College, seventy-one documents were collected, reviewed, and analyzed. These documents provided insight from multiple perspectives and included conference papers, journal articles, college reports, and grant information, as well as other types of documents.

The primary sources of information, that is, information collected from people directly involved in the implementation process within the department, included the transcripts from phone interviews conducted by the researcher with a campus administrator associated with the department and a faculty member in the department, both of whom were active participants in the implementation of initiatives and intimately aware of the implementation details. (To ensure an interview environment in which these individuals felt comfortable sharing their candid perceptions of the processes involved with implementing the initiatives in the computer science department, they were each interviewed with the understanding that their identities would not be revealed.) Additional primary sources included journal articles and conference papers, which documented much of the implementation process and which were all written by faculty and administrators who were directly involved with the initiatives in the computer science department, including Dr. Christine Alvarado, Dr. Zachary Dodds, Dr. Ran Libeskind-Hadas, and Dr. Geoff Kuenning. Other primary sources included grant award information from the National Science Foundation, college reports, and external reports. Each of these provided insight into the processes involved with program implementation.

The secondary sources – news articles, industry news articles, blogs, etc. – were also helpful, as most of them contained information obtained from interviews with the faculty and administrators closely associated with the initiatives in the department. The various angles from which the authors framed their discussions provided details that, in some cases, were not provided in the documents from primary sources. These sources also helped the researcher track the various activities with which those close to the initiatives were involved. In addition, these documents included outside perspectives that helped to frame the initiatives within the broader context of the computer science industry.

Each document was assigned an ID based on the institution (HMC) and the type of document, and this number is referenced in the discussion of findings. Table 4.4 provides a detailed listing of the document types, and Appendix A on page 228 provides a complete listing of all collected documents.

Table 4.4

Collected Documents for HMC

Document Type	Abbreviation	# of Documents
College Information on Website	CIW	4
Conference Paper	CP	2
College Report	CR	9
Department Information on Website	DIW	10
External College News Article	ECNA	1
External College Review Site	ECRS	1
External Report	ER	1
Grant Information	GI	11
Industry Blog	IB	6
Industry News Article	INA	6
Journal Article	JA	4
Journal Article Ad	JAD	1
News Article	NA	9
Participant Interview Transcript	PIT	2
Radio News Transcript	RNT	4

Findings

Numerous documents reveal that faculty and staff in the computer science department at HMC utilized each of the eight strategies in the Transformational Change Model for Inclusive Excellence (TCMIE) to attract more females to the computer science major. Some of these strategies stood out more in the documents than others. These included high impact visible actions, articulation of the rationale for change, ardent support and advocacy from the President of HMC, planned attention to creating empowering settings, and exhaustive efforts to assess and evaluate the programs. Beyond these strategies from the model, external funding and campus culture also seemed to play an important role.

High impact visible actions staged over time.

In 2005, just prior to the most recent change in presidential administration at the College, the faculty in the department of computer science engaged in a strategic plan that identified increasing enrollment and graduation rates of women as a major goal (HMC-03-JA). In the fall of the following year, Dr. Christine Alvarado, a recent graduate of MITs Ph.D. program in computer science, was hired as a faculty member in the department and was immediately involved in the planning that faculty members, led by Dr. Ran Libeskind-Hadas, had been doing. Dr. Alvarado's hiring, as observed in several documents, seemed to provide momentum for the faculty's efforts, which ultimately led them to focus on three major initiatives (HMC-11-PIT; HMC-12-PIT; HMC-15-NA; HMC-53-RNT).

New introductory computer science course.

The first strategy was to re-design the introductory computer science course required of all first-year students. Although documents indicated that this course had been well received by students who were already familiar with and interested in computer science, the faculty in the department decided to design a new course to give students who were less familiar with computer science a "breadth-first" overview of the discipline. First-year students registering for their required computer science introductory course then had the option of choosing between two introductory courses in their first year, one geared toward students who were more familiar with and accomplished in programming prior to coming to HMC, the "black" course, and the new course for less experienced programmers, the "gold" course. (Note: Black and gold were selected because they are the College's colors.) The specifics of this new introductory course were detailed in the following documents: HMC-03-JA; HMC-06-CIW; HMC-13-CP; HMC-44-CIW;; HMC-32-DIW; HMC-33-DIW; HMC-37-DIW; HMC-50-IB; HMC-71-IB; HMC-10-INA; HMC-43-INA; HMC-66-INA;; HMC-04-JA; HMC-05-JA; HMC-07-JA; HMC-14-NA; HMC-47-NA; HMC-69-NA; HMC-11-PIT; HMC-12-PIT; HMC-53-RNT; HMC-51-INA.

There were several aspects of the gold course that distinguished it from the traditional introductory course. First was the choice of programming language. "Java, a notoriously opaque programming language, was replaced by a more accessible language called Python," explained Dr. Klawe in an interview for the *New York Times* (HMC-14-NA). In addition, several documents reveal that faculty thought it was necessary to engage students in writing programs early in the course, as a way to engage them in thinking about how to solve problems. Alvarado, Dodds, and Libeskind-Hadas explained this further in *ACM Inroads*.

> We believe that students should be writing interesting programs from day 1 (or perhaps day 0). However, even Python's relatively simple syntax takes some time to learn and it can be a week or two before students write programs that they find compelling. Thus, we developed a Karel-like language named Picobot that allows students to write interesting programs after the first day of class (HMC-04-JA).

The faculty explained in several journal articles that starting with both the Picobot exercises and utilizing the Python programming language early in the course diminished students' perceptions that some of their peers were more advanced than they because these programming languages were new to everyone in the class. Table 4.5 gives a summary of the remaining course curriculum as provided by Dodds, Alvarado, Kuenning, and Libeskind-Hadas in a conference paper.

Table 4.5

Summary of CS for Scientists' Curriculum

Weeks	Paradigm	Samples of the labs and assignments
1-3	functional	integration, random walks, ciphers
4-6	low-level	recursion, in assembly, 4-bit multiplier
7-9	imperative	Markov text generation, game of life
10-12	objects/classes	Connect Four player, Sudoku solver
13-15	CS theory	uncomputability, finite-state machines

Note. Adapted from "Breadth-First CS 1 for Scientists," by Z. Dodds, C. Alvarado, G. Kuenning, and R. Libeskind-Hadas, 2007, *ITiCSE* '07, Dundee, Scotland, United Kingdom.

According to Alvarado and Dodds, "[c]ollectively, these modules provide students with an understanding of the breadth of modern computational thought, its connections with other disciplines, and skills and tools for writing their own substantial programs" (HMC-03-JA).

***Grace Hopper Celebration of Women in Computing*.**

The second initiative involved inviting first-year women to participate in the Grace Hopper Celebration (GHC) of Women in Computing Conference. The annual conference had previously been used as a retention tool and was successful for retaining those already majoring in computer science, so inviting first-year females to participate represented a change in approach. Alvarado and Judson described the conference in *Communications of the ACM*.

> GHC is an annual conference celebrating the accomplishments of women in CS, combining technical talks, targeted workshops, panels focused on issues facing women in the field, and networking events. Since its inception in 1994, it has had a tremendous positive effect on thousands of women, including hundreds of students (HMC-07-JA).

According to Alvarado, Dodds, and Libeskind-Hadas, faculty in the computer science department felt that the conference could be a recruiting tool for first-year students.

> We hoped that GHC could not only help with retention, but could also serve as a recruiting mechanism for students undecided about their majors. We believed that attending GHC would counter the perception of a hostile CS culture and the lack of mentors and role models in the field. In 2006, we began taking first-year women students to GHC. Twelve first-year HMC women attended GHC and the number of HMC attendees has been growing every year since up to 35 first-year women in 2011 (HMC-04-JA).

Additional details about this initiative were chronicled in the following documents: HMC-03-JA; HMC-04-JA; HMC-10-INA; HMC-11-PIT; HMC-12-PIT; HMC-14-NA; HMC-43-INA; HMC-44-CIW; HMC-47-NA; HMC-50-IB; HMC-66-INA; and HMC-69-NA.

Research opportunities for rising sophomores.

The final initiative exposed students to research opportunities in computer science following their first year, even if, or as Alvarado and Dodd noted, especially if, the students had limited experience in computer science (HMC-03-JA). The computer science department already had an active research program in which faculty and rising junior and senior computer science majors were already engaged. Alvarado, Dodds, and Libeskind-Hadas explained why the faculty thought research for rising sophomores would be a good approach.

> Spurred by evidence that research experiences have been shown to increase retention in computer science, we believed that they might be a useful tool for recruiting as well. In 2006, with generous support from the Baker Foundation, we began to offer research experiences to women students in the summer after their first year. These students had not yet declared a major and they had completed either CS1 only or CS1 and CS2 but no additional CS courses. Among the 44 participating women in the 2007-2011 cohorts, 29 chose CS as their major. This 66% rate compares very favorably with the full-college rate across that timespan, which was less than 20% (HMC-04-JA).

According to Alvarado and Dodds (HMC-03-JA), the experiences were designed to ensure that students were successful with their research efforts, so much of the research built on what the students had learned in their introductory computer science courses. The students who worked on more advanced projects were paired with peer mentors and a faculty member. In *ACM Inroads*, Alvarado, Dodds, and Libeskind-Hadas gave an example of a research project that rising sophomores had done.

> In 2007 and 2008 teams of three rising sophomores developed software that integrated the visual input from a web camera with the actuation available on a small, off-the-shelf robot platform, the iRobot Create. Inspired by the Tapia Robotics competition, they developed software that controlled a robot that

> wandered within an unknown environment seeking out distinctive visual markers and returning home (HMC-04-JA).

A complete summary of findings related to high impact visible actions may be found in Appendix C on page 259.

Clear understanding and articulation of the rationale for change.

Numerous documents show that faculty in the computer science department conducted thorough research about why girls and women are not attracted to computer science, why female HMC students were not attracted to the computer science major, what other institutions were doing on their campuses to address these issues, and why these issues were important. In a letter posted on the HMC website, Dr. Klawe explained that this research was conducted prior to program implementation.

> Our success stems from a determined group of CS faculty who selected a small number of approaches to try based on prior research at other institutions and from a supportive campus community that enabled the implementation of these changes. Prior research identified three key factors why females do not major in CS (HMC-44-CIW).

In an interview for an industry blog, she provided additional details about the type of research conducted.

> In 2006, about 10% of our CS majors were female. And at the same time the department was really trying to think about what they could do to change that. And so they essentially did three things. So first of all, they read up and they figured out why females – high school girls – don't want to study computer

science…So they thought about that and read up on what other institutions had done (HMC-71-IB).

As chronicled in numerous news articles, journal articles, interviews, and industry blogs, the faculty identified four major themes from their research efforts – one from their observations in the computer science department and the other three from their extensive research on the topic: 1) Girls do not understand what computer science is; 2) girls do not think computer science is interesting; 3) they do not think they can excel in it; and 4) their image of computer scientists and their lifestyles is not appealing (HMC-44-CIW; HMC-07-CP; HMC-08-CP; HMC-67-IB; HMC-71-IB; HMC-43-INA; HMC-66-INA; HMC-03-JA; HMC-04-JA; HMC-05-JA; HMC-07-JA; HMC-14-NA; HMC-46-NA; HMC-11-PIT; HMC-12-PIT; HMC-68-RNT).

They also identified the reasons why the absence of girls and women in computer science matters: 1) The job opportunities in the sciences are plentiful; 2) the sciences offer high-paying careers that allow flexibility in lifestyle; and 3) a feminine perspective creates opportunities to cultivate new markets and products (HMC-65-ECNA; HMC-66-INA; HMC-68-RNT). As the referenced documents indicate, faculty synthesized this research into clear and concise statements that were articulated as the rationale or impetus for developing new strategies to attract females to the computer science major at HMC. A complete summary of findings related to understanding and articulating the rationale for change may be found in Appendix C on page 255.

Buy-In and advocacy from senior leadership.

Although in many documents Dr. Maria Klawe, the president of HMC, credits the faculty for the cultural shift in the computer science department, it is clear that she became a major advocate for the department's efforts. In fact, in many of the news articles, she was portrayed as responsible for increasing the enrollment and graduation rates of women in computer science at HMC. Following are examples of this portrayal:

- "Klawe's transformation of this small liberal arts college 35 miles east of Los Angeles has sent ripples from Seattle to Silicon Valley" (HMC-47-NA).
- "As president of Harvey Mudd College, a science and engineering school in Southern California, she [Maria Klawe] has had stunning success getting more women involved in computing" (HMC-54-RNT).
- "Harvey Mudd was already revamping its computer science curriculum when Klawe arrived, and she sped up the plans" (HMC-47-NA).
- "Klawe has 'actually moved the numbers,' says Sheryl Sandberg, chief operating officer of Facebook" (HMC-47-NA).

In addition to these portrayals, many of the news articles focused on her credentials and leadership experiences, which all seem to have elevated her to celebrity status, not only as president of HMC but also as a thought-leader and advocate for cultural transformation within the STEM disciplines. Following is an example of how an industry blog characterized Klawe.

> A renowned computer scientist and scholar, President Klawe is the first woman to lead the college since its founding in 1955. Prior to joining HMC, she served as Dean of Engineering and Professor of Computer Science at Princeton University. During her time at Princeton, Maria led the School of Engineering and Applied Science through a strategic planning exercise that created an exciting and widely embraced vision for the school. At Harvey Mudd College, she led a similarly

> ambitious strategic planning initiative, "HMC 2020: Envisioning the Future" (HMC-39-IB).

Several articles focused on Klawe's personal characteristics, including whimsical facts such as how she enjoys skateboarding.

> Klawe, herself, shatters the stereotype. Besides her expertise in math, engineering and computer science, she plays trumpet and electric guitar, is a serious watercolor artist, and can often be seen traversing the Harvey Mudd campus by her preferred mode of transportation: her skateboard (HMC-65-ECNA).

Other articles focus on her fundraising prowess:

> In her third year on the job, Dr. Klawe landed the largest single contribution in the college's 57-year history - $25 million from R. Michael Shanahan, a financier and the former chairman of Mudd's board, who has since given an additional $6 million (HMC-14-NA).

Evidence of Dr. Klawe's advocacy extends beyond the portrayals of her in the media. Upon assuming the role of president, Klawe ushered in what was described my several as a bold new vision for the entire institution – one that called for HMC to embrace its status as an innovative institution of higher education (HMC-14-NA; HMC-15-NA; HMC-16-CR; HMC-17-CR; HMC-18-CR; HMC-38-IB; HMC-39-IB; HMC-45-NA; HMC-52-INA). It is clear that the goals of the initiative were not just talk, particularly with regard to increasing the number of women and URMs in computer science at HMC. The faculty member interviewed for this study elaborated on Dr. Klawe's commitment.

> She came to Harvey Mudd in the fall of 2006, and basically immediately she threw her resources into these efforts that we had started. She started promoting them by talking to other people about them. She started giving us money. It was clear that we in the department were going to be rewarded for doing these activities. Typically you might think if you do diversity initiatives, it's going to be a "ding" on your career. You should be spending your time on research…But it was very clear that she was going to make it something that was good for your career (HMC-11-PIT).

As an example, in a *Forbes* article, Dr. Klawe was unequivocal in asserting that tenure is not achievable at HMC without demonstrating a commitment to quality teaching and learning experiences.

> We're the only place in the country where you can teach this quality of student – we're competitive with MIT, Caltech and Stanford – and be rewarded for teaching. That's not to say we don't value research, but if you're a crummy teacher, I can tell you that you won't get tenure here (HMC-15-NA).

This was further echoed in position descriptions for open faculty positions that included a statement on the department's interest in creating a diverse community of scholars that was beyond perfunctory. A position announcement in *The Journal of Blacks in Higher Education* illustrates this.

> The candidate must be committed to recruiting, teaching, and retaining a broadly diverse student body including, but not limited to, African Americans, Pacific Islanders, women, persons with disabilities, and other groups underrepresented in computer science. Candidates from these groups are especially encouraged to

> apply. All candidates are invited to describe explicitly the nature of their commitment and experience with underrepresented groups (HMC-24-JAD).

These statements were backed up with policy, although there is not enough information in the collected documents to determine whether these policies were already in place or whether they were implemented as a result of Dr. Klawe's influence. Regardless, it appears that Dr. Klawe was supportive of policies in the *Faculty Notebook*, which outlines faculty reappointment, promotion, and tenure guidelines and provides examples of the criteria that support tenure.

> Regarding ability as a teacher: demonstrated awareness of the strengths and weaknesses of one's students and the ability to make suitable adjustments to the content, organization, and pacing of course work; care and imagination in the preparation of course material, with attention to the relation of this material to the college curriculum and the students' educational needs; development of particularly effective strategies for the educational advancement of all students, including those strategies that contribute to the diversity of the campus; competence in and enthusiasm for the subject taught; demonstrated attention to high standards of scholarship; encouragement of creative activity and an enthusiasm for learning in one's students (HMC-19-CR).

Further evidence of Dr. Klawe's support, offered in several documents, is that she consistently provided financial support, such as partially funding students to attend the annual Grace Hopper Celebration (HMC-11-PIT, HMC-12-PIT, HMC-14-NA; HMC-46-NA). "For funding people like [Mike Erlinger, the chair of the department at that time] and Maria [Klawe] took care of a lot of funding that was needed to run the trip," explained the faculty member interviewed for this study. A *New York Times* article further noted, “Dr. Klawe supported the cause wholeheartedly, and provided money from the college for every female freshman to travel to the annual Grace Hopper conference…” (HMC-14-NA).

In addition to providing financial support, numerous documents reveal that Dr. Klawe was actively engaged in recruitment efforts during the earlier phases of implementation, such as handwriting personal notes for prospective students who were considering computer science (HMC-12-PIT; HMC-14-NA). A *New York Times* article described this commitment.

> Dr. Klawe sometimes does the recruiting herself, sending personal messages to fence-sitters. ‘You tell her about a kid you really want and within four seconds, she’s sent an email,’ said Thyra Briggs, Mudd’s vice president for admission and financial aid (HMC-14-NA).

Additionally, numerous documents indicate that Dr. Klawe regularly participates in orientation experiences for women, speaks at numerous conferences about women in the sciences, and provides interviews with journalists from a variety of media outlets, making sure to tell her stories about how women can achieve in the STEM disciplines (HMC-65-ECNA; HMC-44-CIW; HMC-22-CR; HMC-38-IB; HMC-39-IB; HMC-67-IB; HMC-66-INA; HMC-14-NA; HMC-15-NA; HMC-46-NA; HMC-47-NA; HMC-48-NA; HMC-69-NA; HMC-53-RNT; HMC-54-RNT; HMC-68-RNT).

Klawe’s advocacy seems to stem from her background in mathematics and computer science and some of the personal experiences she had as a young girl, as a college student, professor, administrator, and employee in male-dominated disciplines and industries. In numerous articles, she recounted these experiences. A sampling of these quotes follow.

> When I was a child I pretty much liked everything, but especially math, music and poetry. I turned 60 this year [2011] so when I was a child, girls didn't do math and didn't do engineering. I was determined to do everything that boys did. So initially I decided I would study engineering because it was a way to combine math and art, science and design, as well as doing something that girls didn't do (HMC-53-RNT).

> Professors would say to me all the time, why do you want to be a mathematician, Maria? There are no good women mathematicians. And it really bugged me (HMC-54-RNT).

> I had to learn to use things other than rational argument to get things to happen because in the view of some of the other board members I was just a nuisance…I run into this over and over again in my life. People meet you and think that all of my opinions are based solely on my academic experiences so they are not going to have any validity in the business world (HMC-39-IB).

> I'd say that the things that I do are controversial because I'm constantly pushing for change. Sometimes you do have to push, but the more you can get where people feel that they are making the change because they want to make the change, the more likely the change will succeed and last (HMC-39-IB).

In summary, numerous documents show that Dr. Klawe's visibility at functions internal and external to the College, her cultivation of a campus culture that is accountable to its lofty diversity goals, and her tangible commitments of time and resources to the department of computer science, all of which are influenced by her personal and professional experiences in male-dominated STEM disciplines, likely contributed to the cultural transformation within the department of computer science. Additional findings related to senior buy-in and advocacy may be found in Appendix C on page 256.

Planned attention to the environment for women and URMs.

The climate fostered as a result of the three initiatives within the department meets the criteria that Maton (2008) described as critical to developing empowering settings for underrepresented student populations. These criteria include a strengths-based belief system; a pervasive, highly accessible, and multi-functional role structure; a system that addresses the holistic needs of the students and that provides a sense of community; and program leadership that is highly skilled, and committed to the students.

In an interview for OneDublin.org, Dr. Klawe summarized the strengths-based approach that is emphasized for all entering students.

> From day one we tell our students that we know you were one of the best students in your high school, and you probably didn't work in teams because you didn't need to. You were the person that helped others get through their math or science course or whatever, and what we do at Harvey Mudd is make the curriculum so challenging that virtually no student will be able to do it on their own. And we also set it up to encourage you to work with others, and we joke that having fun in

> the evening at Mudd is being part of a group that is doing your physics homework or your computer science homework or your math homework. It's a great approach because by the time students graduate, they have had a lot of experience working with people who have different strengths and different approaches, and they know how to make that work (HMC-53-RNT).

In a college review site external to HMC, anonymous students further elaborated on this philosophy. Quite Bright [anonymous student's screen name], a computer science major, offered an example.

> The workload is literally so hard that it's nearly impossible to get it done by yourself, so everybody works together. The mindset of the professors is something like "we're going to make it so hard you can't do it by yourself, and then we're going to let you work with your friends and be available at all hours to make sure you figure it out" (HMC-70-ECRS).

These expressions of support are in contrast to the "weeding out" introductory courses that are often cited in the literature (Cabrera, Colbeck & Terenzini, 2001; Maton, Hrabowski, Schmitt, 2000).

In a conference paper, Alvarado and Dodds provided an explanation of how the three major initiatives contributed to an environment in which women computer science majors could thrive.

> We split students into a standard track for those without experience and an enrichment track for those with prior CS background. We offer two sections of the standard track and one section of the enrichment track, each with about 60 students. This separation keeps the latter students challenged without

> intimidating students new to CS. Second, we implemented optional, but incentivized, faculty-staffed closed lab sessions each week. Students can attend a weekly, two-hour lab and receive full-credit for one of the three or four weekly homework problems, regardless of whether they finish the problem or not. This arrangement lessens the workload for inexperienced students and, even more importantly, allows them to get early help with difficult concepts (HMC-03-JA).

They went on to explain how they thought first-year women would benefit from attending the GHC. "We believed that interactions with the professionals at GHC would reinforce *experientially* the opportunities we sought to present in the curriculum (HMC-03-JA). Additionally, they highlighted the significance of the research experiences for rising sophomores.

> The only thing missing for incoming women was the confidence to feel that they too could do real-world computer science. To this end, we organized research experiences for rising sophomores…Although these students had very little experience (one or two semesters of CS) they made concrete progress on real research problems (HMC Document 10).

These research experiences also served to help frame computer science as an area of study that has social relevance, which the literature has shown is attractive to many women (Vaz, 2013; Wang, Eccles & Kenny, 2013). An article about Dr. Klawe's speech to Elmhurst College alumni explained how this was so.

> "There's so many different ways you can use that knowledge to make a difference in the world today," said Klawe, citing examples of CS grads working on modeling for epidemiology to study the spread of disease in Africa, or

> applications in anthropology or economics. "It's one of the most versatile set of skills you can have today. And the job opportunities are phenomenal" (HMC-65-ECNA).

An interesting outcome, though perhaps not intentional, was that creating empowering settings for women also seemed to have an effect on men who did not fit the stereotypical profile of computer scientists. Alvarado, Dodds, and Libeskind-Hadas explained this in a journal article in *ACM Crossroads*.

> While we initially strived to increase the number of first-year women in our summer research program, that effort has also led to a large increase in the number of men participating, too. Over the last five years, twenty-nine rising sophomore men have participated in research, up from a total of four in the two years prior. Twenty of those twenty-nine chose CS as a major: the same two-thirds conversion rate as among the rising-sophomore women (HMC-04-JA).

Another interesting finding is that underrepresented student populations were not the only ones challenged to think differently about computer science. It appears that traditional computer science students, those in the "Black" introductory courses were also challenged to view computer science in a different light. Alvarado, Dodds, and Ran Libeskind-Hadas provide an example of this in their article in *ACM Inroads*.

> In fact, the Black/Gold split has a less touted, but equally important benefit: in the Black section we help debunk some of the misconceptions that experienced students bring to CS, e.g., that mastery of syntactic constructs is central to the field – or that CS is merely programming (HMC-04-JA).

Additionally according to an article written by Dr. Klawe and published in the *IEEE Computer Society*, these students are strongly encouraged not to engage in "intimidating" behavior.

> In all introductory CS courses, instructors deliberately discourage the most experienced students from intimidating others in class by showing off their knowledge. Eliminating this "macho" effect has significantly improved the culture in all CS courses at HMC, resulting in a more supportive learning environment for all (HMC-43-INA).

Eliminating the "macho" effect, she further explained, "requires a modest amount of extra time from instructors and has a huge payoff" (HMC-43-INA). In one article, she refers to this "macho" effect as hazing. "We've also eliminated hazing and have become very good at nurturing," she said in a *Forbes Woman* article (HMC-15-NA). The administrator interviewed for this study described this nurturing approach.

> They [faculty] came up with the idea of having private conversations with these students one-on-one and just saying, "You know, Joe. I love having you in my course. It's amazing how much you know. You're so passionate, so talented. It's just great. What you probably don't realize is that there are a few students who are intimidated by how much you know, so it would be great if we could have our conversations in private out of class, not in class." And that's generally extremely effective because that particular individual was not trying to be intimidating to the other student. They were just passionate and enthusiastic about computer science and finally had the chance to talk to somebody who understood what they were talking about (HMC-12-PIT).

Beyond the three major initiatives, there was an emphasis on the "psychological obstacles" that students face (HMC-69-NA). An article in *The Wall Street Journal* summarized Dr. Klawe's role in addressing these obstacles and the research behind the obstacles.

> Dr. Klawe also took on psychological obstacles. Research shows women, more than men, see having to exert a lot of effort to pass STEM classes as a sign that they don't belong, according to a 2012 study headed by Jessi L. Smith, an associate professor of psychology at Montana State University; women who are encouraged to see working hard as normal and expected are more likely to stick with STEM. The college president tackles the topic of self-doubt in her annual address to incoming freshmen (HMC-69-NA).

In a *Forbes* article, Dr. Klawe described how this self-doubt tends to affect women.

> The reluctance of women to enter STEM fields seems to have deep roots – which often don't disappear even in the face of success. One of Dr. Klawe's favorite topics is what she calls The Imposter Syndrome. "Even women who get into MIT, and major in engineering," she says, "often continue to second guess themselves, worrying that success was a mistake. So the first time they get a B on an exam, they switch to a major in the humanities. Yet males can get all C's and think they're doing great. It's just normal for males to overestimate their success and for women to worry that they don't deserve to be where they are. That insecurity often haunts them into their professional lives" (HMC-15-NA).

To counter these messages of self-doubt, Dr. Klawe offers two messages that she shares with students. She described these messages during an interview with One Dublin.org.

> My first message is hard work is much more important than being super smart. The reason I say this is that in our country we tend to think of math and science as something you're born good at rather than something you work hard to be good at, whereas with basketball or baseball or music we know practice makes a huge difference. It doesn't matter who learns math faster. What matters is whether you put in the time and perseverance in actually learning the material thoroughly. Everybody can be good at math. It's a question of hard work and persistence more than anything else, and if it takes you a long time to learn something, that doesn't mean you aren't going to be good at it. It just means it took you a long time to learn it (HMC-53-RNT).

She then reassures them with her second message.

> It often happens that even though a student seems to be doing very well, he or she doubts that they really deserve the success that they have. Because of that doubt, if something goes wrong and the student gets a poor grade unexpectedly, or has a teacher who doesn't express confidence in their ability to succeed in the course, the student may not work as hard and then not do as well. It's important to know that the imposter syndrome is something that many people suffer from, and that it's persistence and hard work that will make the difference, and that if you just keep pushing on it and get encouragement and help from others, you're going to do just fine" (HMC-53-RNT).

She even shares her own experiences, such as she did during an interview for a Canadian IT blog.

> What I realized over time is that whenever I start something new…I just think I'm going to be a total failure at it. Of course the most important thing is to not stop yourself from doing things just because you think you are going to be a total failure, and the important thing is to just do it (HMC-39-IB).

Additional findings related to planned attention to the environment for women may be found in Appendix C on page 258.

Continuous assessment and evaluation.

Assessment and evaluation were the tools that gave the faculty in the department a sense of direction throughout the transformation process. Several documents reveal that they have collected a variety of useful information since the implementation of the three major initiatives in the department. For instance, they track participation, including the number and percentage of women choosing CS as a major. According to Alvarado in a paper for the Special Interest Group on Computer Science Education (SIGCSE) in the Association for Computing Machinery (ACM), "We focus on incoming classes since 2003: three years before and three years after the three new practices" (HMC-03-JA). Alvarado also noted that they also tracked trends in computer science course choices among the entire student body, with careful attention to accommodating "the high variance in the yearly raw numbers at our small institution" (HMC-03-JA). In addition to collecting participation numbers, the faculty in the department also conducted student surveys, as described by Alvarado.

> [W]e conducted two student surveys to get a better understanding of how our initiatives impacted our students: a single broad student survey aimed at all of our students (the "CS Experience Survey") and a smaller annual survey aimed at GHC attendees (HMC-03-JA).

As described in an article for *ACM Inroads*, in subsequent years they also collected information from their alumni.

> Through email, we invited all current and just-graduated students (classes of 2009-2012) and all CS major alumni back to the class of 2007 to take our survey. A total of 449 of 784 invited responded, a 57% response rate. Those who responded comprise a representative swath of the overall demographics of the college in terms of gender and race, and the 58% response rate of CS majors was approximately equal to the overall response rate (HMC-04-JA).

The faculty also administered pre- and post-surveys to the participants and student mentors in regard to their experiences at the GHC. According to Dr. Alvarado in a blog for the University of California San Diego (UCSD), for example, "We have been administering the same pre and post survey [for GHC attendees] over the past several years" (HMC-02-IB).

The results of their assessment and evaluation efforts provided the information necessary to make adjustments to the three initiatives as necessary. Alvarado, Dodds, and Libeskind, as an example, discussed some of the lessons they learned from evaluations in *ACM Inroads*.

> We have found that we are more successful when we recruit students during the summer, before they have finalized their fall schedules. We send all admitted

female students a recruiting email in June before matriculating to HMC, asking them to commit by mid-July. This early action not only generates considerable student interest, but it also helps with our planning and scheduling (HMC-04-JA).

Ultimately, the faculty member interviewed for this study noted, assessment and evaluation have served to provide validation for their choice of initiatives, as well as for the underlying premise that varying the methods of instruction to cater to the needs of underrepresented students does not undermine excellence. That faculty member summarized how surprising the results were to the faculty involved.

> I don't think any of us expected it [the three-part initiative in the computer science department] to be so successful. And then we started assessing what we had done, that is, measuring numbers, and we were all surprised. I think the assessment really helped us see how much of a difference it had made and maybe gave us the leverage to keep going with it (HMC-11-PIT).

Additional findings related to continuous assessment and evaluation may be found in Appendix C on page 260.

External Funding.

Funding for each of the three major initiatives likely influenced the success that the three initiatives have had in the department of computer science, particularly for the GHC and research initiatives. On her blog, Christine Alvarado, provided details about the funding that allowed HMC students to participate in the annual GHC conference with all expenses paid for, except meals during transit and some meals during the conference.

> The cost of the trip is $600-$1000 per student depending on where the conference is. We have received both internal and external funds to finance this conference,

> for a total of between $25K to $40K per year. Our department funds $5K per year, and the president's office funds another $5K, in addition to providing money for HMC to be a sponsor of the conference. We have received external donations between $5K and $25K from companies, alumni and individual donors (HMC-02-IB).

Dr. Klawe, in an article for *Computer* further explained how funds are raised for the conference.

> We have found it relatively easy to raise the necessary funds from individuals and companies because the tech industry is genuinely interested in increasing the number of women in related professions. There are now several regional versions of the Hopper conference, making attendance even more affordable. Finally, many foundations provide support for summer research for undergraduates (HMC-43-INA).

Alvarado, Dodds, and Libeskind-Hadas explained why this level of funding is critical.

> We believe that this financial support is critical for our recruiting: a substantial price tag might not deter those with means who are already motivated to study CS, but it is unlikely that students not already considering the field would make such an investment (HMC-04-JA).

Beyond funding for GHC, the computer science department has also received funds to assist with curriculum development and for developing research opportunities for all students, in addition to some funding specifically for female students. Dr. Klawe, in a letter on the HMC website shared details about an NSF grant to fund the CS5 curriculum.

In 2010, the National Science Foundation recognized the breakthrough work occurring at HMC and awarded the CS Department an $800,000 grant to enable HMC to begin exporting the highly successful CS5 course (HMC Document 44).

A summary of grant funding documents collected and associated with the computer science department at HMC is provided in Table 4.6. Additional findings related to external funding may be found in Appendix C on page 261.

Table 4.6

Summary of NSF Grant Awards for CS at HMC

Award Abstract #	Description	Dates	Award Amount
0451293	REU SITE: Harvey Mudd REU Site on Artificial Intelligence, Systems, and Optical Networking – Provided a ten-week summer research experience for undergraduate students, with an emphasis on those from underrepresented populations	May 1, 2005 to April 30, 2009	$286,209.00
0939149	CPATH-2: Modular CS1 from the Inside Out: Computational Thinking for all STEM students – Used to develop course modules based on the successful introductory CS courses at HMC so that other institutions could replicate the course	September 1, 2009 to August 31, 2013	$824,692.00
0910606	CSR: Large: Collaborative Research: Reclaiming Moore's Law through Ultra Energy Efficient Computing – A research effort aimed at reducing national energy consumption and environmental impact with regard to computing	August 1, 2009 to July 31, 2014	$80,000.00
1240939	CER: MyCS – Middle Years Computer Science – Used to develop a CS curriculum to be implemented at middle schools with the goal of developing positive computational identities among middle-school students	May 15, 2013 to April 30, 2016	$596,501.00
1219243	SHF: Small: RUI: Observationally Cooperative Multithreading – A research project involving 18 undergraduate students over three years to develop the Observationally Cooperative Multithreading (OCM) approach to solving problems on parallel machines.	October 1, 2012 to September 30, 2015	$375,395.00
1042472	The Games Network: Games for students, games by students – Addressed student misconceptions about computing by engaging middle school students in a semester-long software development project carried out by college students.	January 1, 2011 to June 2, 2013	$580,033.00
1305360	CRI-CI-ADDO-EN: National File System Trace Repository – A research project to operate and expand IOTTA Trace Repository that makes standardized, high-quality data sets available to researchers worldwide.	September 1, 2013 to August 31, 2016	$130,799.00
1302232	CSR: Medium: Collaborative Research: Workload-Aware Storage Architectures for Optimal Performance and Energy Efficiency – A collaborative research effort with Stony Brook University, Harvard University, and HMC that leverage the team's work on storage-optimized algorithms, multi-tier storage, and new optimized data structures	October 1, 2013 to September 30, 2016	$180,023.00
1359170	REU Site in Computer Systems – Brings 10 undergraduates to HMC to engage them in research and encourage graduate study in computer science	March 1, 2014 to February 28, 2017	$358,068.00
1339404	CER: Import PCK: What 10K Novice Teachers Can Learn from Teachers with 10K Hours of Experience – Collaborative effort of expert computer science educators convened by HMC to document, validate, and promote CS pedagogical content knowledge	October 1, 2013 to September 30, 2016	$723,095.00

Award Abstract #	Description	Dates	Award Amount
TOTAL			$4,134,815.00

Note. Adapted from "Awards Simple Search," National Science Foundation (http://www.nsf.gov/awardssearch/)

Campus Culture.

There is evidence that several aspects of the campus culture contributed to the success of the initiatives in the computer science department. The faculty participant in this study explained how the mission and focus of the school attract students.

> The school is a science and engineering school, so I think that's a bit unusual and provides a bit of context. The students come in, and they're all inclined to study science and engineering, so we're not fighting a battle against people who don't like science. And we're also not fighting a battle against people who don't have mathematical skills…At Harvey Mudd, there's no issue there, because everybody is extraordinarily well prepared (HMC-11-PIT).

In addition, there is evidence that innovation, with regard to instruction, is prevalent even outside the department of physics. An article by Dr. Klawe in *Forbes* magazine, as an example, describes a course that faculty at the school launched in 2009.

> Our students major in STEM fields but also have a concentration in the humanities, social sciences and the arts (HAS). As a liberal arts college, we value students' development as communicators, thinkers and scientists. Since our founding, we have focused on teaching our students to write, but this emphasis was centralized among HAS faculty. To communicate that writing is important across the STEM disciplines, we decided to try something new: engage faculty from all departments to teach WRIT 1, our first-year, half-semester introduction

to college writing. To date, nearly 40% of our STEM faculty members have taught the course, and WRIT 1 has become a favorite part of the new curriculum (HMC-45-NA).

The *2011-2012 Annual Report* at HMC also describes innovations in the engineering department.

What attracted trailblazing professors M. Mack Gilkeson and the late Jack Alford to the then-newly opened Harvey Mudd College was, among other things, the school's expressed willingness to gamble on innovative approaches to teaching. In short order, they convinced HMC to wager on the Clinic Program…It turned out to be a winning wager…Projects undertaken in the Clinic are sponsored by companies, and those endeavors sometimes reap commercially viable fruit, as was the case in October 2011, when tech company Laserfiche expanded its records management system with the addition of a mobile product employing Clinic-developed code. Such real-world experiences help the Clinic Program achieve its ultimate aim: the creation of well-rounded engineers, designers and technology specialists who graduate equipped to persuasively convey innovative ideas to collaborators, business managers, clients, investors and government officials (HMC-22-CR).

That the initiatives in the computer science were situated within the context of the broader community at HMC likely played a role in the initiatives' success. Additional findings about the campus culture at HMC may be found in Appendix C on page 261.

Barriers.

As successful as the initiatives in the department of computer science at HMC were, that success did not come without obstacles. A faculty member explained that navigating conference attendance was challenging.

> The Grace Hopper trips take the students away for two to three days during the fall semester, and it's hard to schedule that. In the beginning, students were potentially going to miss their labs, which was not okay. You can't miss chem [chemistry] lab; they [students] *must* be present for chem lab. In later years it was conflicting with a big physics test (HMC-11-PIT).

According to that same faculty member, the faculty in the department overcame that barrier as much as possible with creative scheduling.

> We started soliciting the applications for the trip in the summer, and then we would choose the students who were going to go. Then we would schedule them into chem labs that would not conflict with the trip. Once it started to be almost half the women coming into the college, it became the case that the Monday-Tuesday chem labs were entirely women, and then the Thursday-Friday chem labs were all men. That created a weird dynamic as well (HMC-51-PIT).

Although more a challenge than a barrier in the earlier phases of implementation, faculty also faced an increased workload, as was captured in two scholarly articles – one in an article in *ACM Inroads* and the other in a SIGCSE conference paper.

> The instructors reported a high level of personal satisfaction teaching computer science using this model [introductory course model], but also indicated that the

> first offering was quite effortful since it was a complete departure from their existing traditional "Java Programming" model (HMC-04-JA).

Another article indicated that the structural changes in the introductory course have "slightly increased the faculty load dedicated to CS1, from 0.8FTEs to 1.2FTEs in the fall semester (the only semester it is offered)" (HMC-03-JA).

According to the faculty member interviewed for this study, however, the challenges the faculty faced with implementing the initiatives were minor. The faculty member speculated, "I could see many more barriers being potentially problematic at other institutions, but as I keep mentioning, the attitude of the department meant everything" (HMC-11-PIT). A summary of findings related to the barriers encountered at HMC may be found in Appendix C on page 262.

The analysis of the documents allowed for a better understanding of the strategies that faculty and administrators at HMC used to advance their goal of increasing the number of female computer science majors. In addition, the analysis also provided some insight into the types of barriers, though few, that faculty in the department faced and the strategies they utilized to overcome them. A complete listing of findings at HMC may be found in Appendix C, starting on page 255.

CHAPTER 5
Massachusetts Institute of Technology – Department of Physics

MIT is a community eager to solve hard problems in service to the nation and the world. Thanks to our students, faculty, staff and 100,000 alumni around the globe, the Institute hums with bold ideas and inspired solutions. – Rafael Rief, President (2014)

Institute Profile

Ranked 18th on the *Forbes* list of best colleges for women in the STEM disciplines (Doss, 2010), the Massachusetts Institute of Technology (MIT), which is located in Cambridge, Massachusetts less than ten minutes from Harvard University, was incorporated by the Massachusetts Commonwealth in 1861 (MIT, 2014). An independent, coeducational, and privately owned institution, MIT is classified by Carnegie (2013) as a research institution with very high research activity (RU/VH). The mission of MIT is to "to advance knowledge and educate students in science, technology, and other areas of scholarship that will best serve the nation and the world in the 21st century" (MIT, 2014). To advance this mission, the Institute offers 46 undergraduate majors and 49 undergraduate minors in five schools– the School of Architecture and Planning; the School of Engineering; the School of Humanities, Arts, and Social Science; the MIT Sloan School of Management; and the School of Science – and over 30 departments. In addition, the Institute provides class lectures, notes, exams, and videos through MITs Open Course Ware, which is accessible to the general public, and it offers over 200 courses through edX, its online-learning initiative.

During the 2013-2014 academic year, MIT enrolled a total of 11,301 students – 4,528 undergraduates and 6,773 graduates – from 50 states, the District of Columbia, three territories, and 114 foreign countries (MIT, 2014). In terms of ethnic diversity, 36.9 percent of the undergraduate students were White, 23.9 percent Asian, 16.4 percent Hispanic, 9.9 percent Non-Resident Alien, 5.3 percent Black, 5.05 percent Two or More Races, 2.3 percent were of Unknown Race, and less than 1 percent were American Indian/Alaska Native. In addition, 44.8 percent of the undergraduate population was female. With a freshman acceptance rate of 8.2 percent, 99 percent ranked in the top 10 percent of their high school class, and students in the 25th percentile scored above 680 on all areas of the SAT, with the highest scores in math (MIT, Institutional Research, 2014). Following graduation, 40 percent of those with bachelor's degrees went on to graduate school, and 53 percent went directly into the workforce, with average starting salaries of $64,523 (MIT, Admissions, 2014).

During that same year, MIT employed a total of 1506 faculty, 88 percent of which held Ph.D.'s or the highest degree in their fields (MIT, 2014). This allowed for an 8 to 1 student-to-faculty ratio. In terms of gender and ethnic diversity, female faculty members comprised 26.1 percent of the faculty, while minorities comprised 15.5 percent. Among the faculty there have been 80 Nobel Laureates, 39 National Medal of Science recipients, 43 MacArthur Fellows, 11 recipients of the John Bates Clark Medal, 4 recipients of the Pulitzer Prize, and 27 National Medal of Technology and Innovation winners. Additionally, 77 were members of the National Academy of Sciences, 63 were members of the National Academy of Engineering, and 33 were members of the National Institute of Medicine.

With tuition at $44,720 for undergraduates and room and board at $13,224, nearly 61.8 percent of students received financial aid up to $44,720 (MIT, 2014). The College had an annual operating budget of $2,908.6 million and an endowment of $17 billion as of 2013 (MIT News Office, 2013). Table 5.1 provides a brief summary profile of the Institute.

Table 5.1

MIT Brief Profile: 2013-2014

Area of Interest	**Description**
Undergraduate Enrollment:	4,528
Graduate Enrollment:	6,773
Gender Ratio Undergraduate:	45 percent
Gender Ratio Graduate:	31 percent
Ethnic Distribution:	American Indian/Alaskan Native – 2 percent Asian American – 30 percent Black/African American – 8 percent Hispanic/Latino – 17 percent Native Hawaiian/Pacific Islander - <1 percent White/Caucasian – 52 percent No indication – 2 percent Note: Some students indicate more than one ethnicity
Student Distribution:	Asian American – 30 percent
Admissions Acceptance Rate:	8.2 percent
Freshman Class:	99 percent in top 10 percent of class
Freshman SAT Scores: (Range includes scores at the 25th and 75th percentile)	SAT Critical Reading: 680 – 770 SAT Math: 750 – 800 SAT Writing: 690 – 780
Freshman ACT Composite	33-35 (based on 25th and 75th percentile)
Student-to-faculty ratio:	8:1
Students living on campus:	88 percent
Faculty	1,128 Full-time; 278 Part-Time; 1506 Total 88.0 percent hold Ph.D. or highest degree in field
Female Faculty	26.1 percent
Minority Faculty	15.5 percent
Tuition:	$44,720 (Undergraduate)
Room and board:	$13,224 (Undergraduate)
Financial Aid	61.8 percent received some financial aid up to $44,720
Placement in Graduate or Professional School:	35 percent
Placement in Workforce (2013):	65 percent
Average starting salary (2013):	$73,567 (for students with bachelor's degree)
Endowment (2013):	$17 billion
Annual operating budget:	$2,908.6 million

Note. Adapted from "MIT Facts," (http://web.mit.edu/facts/) and *IPEDS Data Center*, National Center for Education Statistics (http://nces.ed.gov/ipeds/datacenter/)

Department of Physics Profile

The Department of Physics, formed in 1865 and currently housed in the School of Science, has been ranked number one by *U.S. News and World Report* for physics departments in the United States since 2002 (MIT Department of Physics, 2013, From the Department Head), and in April of 2013, the American Physical Society (APS) awarded the department for "Improving Undergraduate Physics Education," one of only four institutions recognized for doing so (MIT Department of Physics, 2013, MIT Physics News Spotlight). Describing the reason MIT's department received the award, the APS (2012) noted that

> MIT has engineered an impressive transformation of its undergraduate physics curriculum, which currently produces the largest number of bachelor's degrees in physics annually of any university in the United States. The Department has more than doubled the number of majors since 2001, accompanied by a focus on diversity that has resulted in a department in which more than a third of graduating seniors are women. These changes have been accomplished through a focused commitment to creating a program that is flexible, welcoming and respectful of all students, with advising, mentoring and other programs to support students at all levels.

The department is comprised of 24 faculty emeriti, 54 full professors, 10 associate professors, 18 assistant professors, 6 senior research scientists, 3 lecturers, 3 senior lecturers, and 38 administrative staff, which makes it the largest faculty in the School of Science (MIT, Department of Physics, 2014b). These faculty conduct research in four main areas: astrophysics; atomic, biophysics, condensed matter, and plasma physics;

experimental nuclear and particle physics; and theoretical nuclear and particle physics. Four have earned Nobel Prizes. Table 5.2 provides more information about the physics department as it compared to other departments in the School of Science during the 2013-2014 academic year.

Table 5.2

Brief Overview of Departments in the School of Science at MIT: 2013-2014.

Department	**Number of Faculty and Staff**	**Majors**	**Percent Distribution of Students**
Biology	76 faculty 40 staff 116 total	• Bachelor of Science in Biology 7 • Bachelor of Science in Biology 7A	15.8 percent 1.2 percent
Brain & Cognitive Sciences	48 faculty 36 staff 84 total	• Bachelor of Science in Brain and Cognitive Science	13.1 percent
Chemistry	31 faculty 75 staff 106 total	• Bachelor of Science in Chemistry	6.7 percent
Earth, Atmospheric & Planetary Sciences	65 faculty 32 staff 97 total	• Bachelor of Science in Earth, Atmospheric & Planetary Sciences	2.3 percent
Mathematics	73 faculty 20 staff 93 total	• Bachelor of Science in Mathematics • Bachelor of Science in Mathematics and Computer Science	26.9 percent 10.2 percent
Physics	106 faculty 50 staff 156 total	• Bachelor of Science in Physics	23.8 percent

Note. Adapted from "MIT School of Science," MIT, 2014 (http://science.mit.edu/academicprograms/graduate and IPEDS Data Center, National Center for Education Statistics (http://nces.ed.gov/ipeds/data Center/

Since 1998, the department has seen the most growth in the number of female graduates. During the 1998-1999 academic year, 7 out of 41 graduates (17.0 percent) were females, in comparison to 32 out of 77 (41.6 percent) in the 2010-2011 academic year (NCES, 2014). The department has not seen as much success with URMs, however, they typically graduate more than the national average. Table 5.3, Figure 5.1, and Figure 5.2 provide additional information about degree completions in the physics department by gender and ethnicity.

Table 5.3

Physics Degree Completions by Gender and Ethnicity

	1998-1999		2000-2001		2002-2003		2004-2005		2006-2007		2008-2009		2010-2011	
	#	%	#	%	#	%	#	%	#	%	#	%	#	%
Male	34	82.9	47	85.5	41	67.2	58	74.4	60	70.6	60	73.2	45	58.4
Female	7	17.1	8	14.5	20	32.8	20	25.6	25	29.4	22	14.7	32	41.6
AIAN	0	0.0	0	0.0	0	0.0	3	3.8	0	0.0	0	0.0	1	1.3
Asian	5	12.2	7	12.7	15	24.6	10	12.8	21	24.7	13	15.9	14	18.2
BAA	0	0.0	3	5.5	3	4.9	0	0.0	5	5.9	0	0.0	0	0.0
H/L	3	7.3	4	7.3	2	3.3	5	6.4	5	5.9	7	8.5	8	10.4
NHOPI*	-	-	-	-	-	-	-	-	-	-	-	-	0	0.0
NRA	5	12.2	12	21.8	7	11.5	14	17.9	7	8.2	11	13.4	11	14.3
RU	0	0.0	6	10.9	7	11.5	10	12.8	13	15.3	7	8.5	6	7.8
TMR*	-	-	-	-	-	-	-	-	-	-	-	-	1	1.3
White	28	68.3	23	41.8	27	44.3	36	46.2	34	40.0	44	53.7	36	46.7

Note. Bold line indicates the year of the first graduating class after introduction of flexible major. AIAN = American Indian/Alaska Native. BAA = Black/African American. H/L = Hispanic/Latino. NHOPI = Native Hawaiian or Other Pacific Islander. NRA = Non-Resident Alien. RU = Race Unknown. TMR = Two or More Races. NCES did not separate out NHOPI and TMR prior to 2010-2011. Adapted from "MIT School of Science," MIT, 2014 (http://science.mit.edu/academicprograms/ graduate and IPEDS Data Center, National Center for Education Statistics (http://nces.ed.gov/ipeds/data Center/.

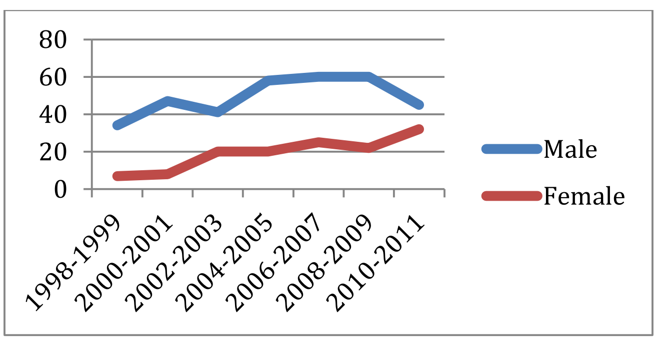

Figure 5.1 Chart illustrating physics degree completions at MIT by gender. Adapted from IPEDS Data Center, National Center for Education Statistics (http://nces.ed.gov/ ipeds/datacenter/).

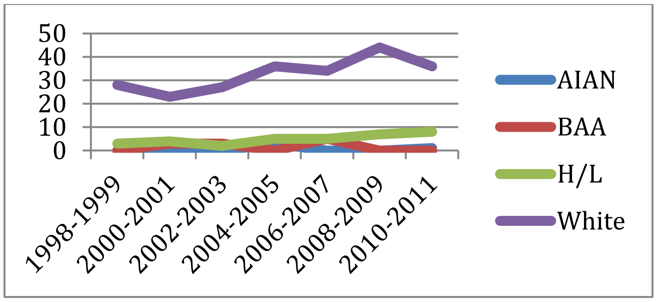

Figure 5.2 Chart illustrating physics degree completions at MIT by ethnicity. Adapted from IPEDS Data Center, National Center for Education Statistics (http://nces.ed.gov/ipeds/datacenter/).

After graduation students go on to work at places like AdHarmonics, Boston Consulting Group, DC Energy, Facebook, Google, Jane Street, Kyruus, Max Planck Institute for Quantum Optics, MIT's Laboratory for Nuclear Science, Nabsys, Newton Public Schools, Oracle, and SRA International (MIT, Global Education Career Development, 2013).

Document Collection Overview

To facilitate an understanding of the strategies that faculty and administrators in the physics department utilized to increase the graduation rates of women, one hundred and two documents were collected, reviewed, and analyzed. These documents provided insight from multiple perspectives and included conference papers, journal articles, college reports, and industry news articles, as well as other types of documents.

The primary sources of information, that is, information collected from people directly involved with the implementation of the various initiatives associated with the increase in female students and/or directly involved with the current facilitation of these initiatives, included the transcripts from phone interviews conducted by the researcher with two faculty members in the department and an outside staff member who worked with the physics department on several initiatives. (To ensure an interview environment in which these individuals felt comfortable sharing their candid perceptions of the processes involved with implementing the initiatives in the physics department, they were each interviewed with the understanding that their identities would not be revealed.) Additional primary sources included journal articles, which documented much of the implementation process. Most of these were written by faculty and administrators who were directly involved with the initiatives in the physics department, including Dr. John Belcher, Dr. Yehudit Judi Dori, Mark Bessette, Michael Danzieger, Andrew McKinney, and Dr. Erin Hult. Other primary sources included college reports. Each of these provided insight into the processes involved with program implementation.

The secondary sources – news articles, industry news articles, industry reports, blogs, etc. – were also helpful, as many of them contained information obtained from interviews with the faculty and administrators closely associated with the initiatives in the department or from awards the department received as a result of their efforts. The various angles from which the authors framed their discussions provided details that, in some cases, were not provided in the documents from primary sources. These sources also helped the researcher track the various activities with which those close to the initiatives were involved. In addition, these documents included outside perspectives that helped to frame the initiatives within the broader context of the physics community.

Each document was assigned an ID based on the institution (MIT) and the type of document, and this number is referenced in the discussion of findings. Table 5.4 provides a detailed listing of the document types, the abbreviations for the document types, and the number of documents collected in each category. A complete listing of collected documents is on page 235 of Appendix A.

Table 5.4

Collected Documents for MIT

Document Type	Abbreviation	# of Documents
College Blog	CB	3
College News Article	CNA	21
College Report	CR	22
Department Information on Website	DIW	4
External College Review Site	ECRS	2
Facebook Page	FB	1
Industry Blog	IB	2
Institute Information on Website	IIW	21
Industry Keynote Address	IKA	1
Industry News Article	INA	10
Industry Report	IR	1
Industry Wiki Page	IW	1
Journal Article	JA	5
News Article	NA	4
Participant Interview Transcript	PIT	3
Personal Blog	PB	1
TOTAL		102

Findings

Numerous documents reveal that faculty and staff in the physics department at MIT utilized each of the eight strategies in the Transformational Change Model for Inclusive Excellence (TCMIE) to attract more females and URMs to the physics major. Some of these strategies stood out more in the documents than others. These included high impact visible actions staged over time, articulation of rationale for change, buy-in from senior leadership, collaborative leadership at multiple levels, planned attention to the environment for women and URMs, and assessment and evaluation. Beyond the study framework, external funding, campus culture, and MIT's admissions office seemed to also play important roles in the department's success.

High impact visible actions staged over time.

There were several major initiatives both internal and external to the physics department that were visible and staged over several years. These included the flexible major option, the Technology Enabled Active Learning (TEAL) format for introductory physics courses, and other initiatives, such as those offered by the Office of Minority Education (OME).

Flexible major option.

According to a report in the MIT Physics Annual (MIT-31-CR), prior to the year 2000 the physics department offered one primary undergraduate degree program, referred to in the catalog as VIII. This program of study had nine required courses, along with 12 units of thesis, one elective course in mathematics, and two elective physics courses in either Electromagnetism II, Statistical Physics II, or Classical Mechanics II. This program of study, now commonly referred to as the focused option, was geared toward students who were interested in continuing their study of physics in graduate school.

In 2000, under the leadership of the Associate Department Head for Education Dr. Thomas Greytak, the physics department implemented an undergraduate degree program, VIII-B, which is now commonly referred to as the flexible major option. Dr. Greytak described the differences in this new major.

> Both the VIII and VIII-B programs lead to the same degree, a Bachelor of Science in Physics. VIII-B requires fewer specific upper level subjects in physics. They are replaced by a student-designed three-subject "focus group" that builds on the earlier foundation subjects in physics. The subjects in the focus group are not restricted to physics but in general are chosen to prepare the student for a

particular, though not necessarily traditional, career path…There are two other differences between VIII and VIII-B: VIII-B only requires one term of laboratory work while VIII requires two, and VIII-B does not require a senior thesis (MIT-31-CR).

According to several documents, this new flexible major option was instantly popular among students (MIT-13-CR; MIT-14-INA; MIT-22-PIT; MIT-31-CR; MIT-32-CB; MIT-33-IKA). Figure 5.3 shows the requirements for both options, as provided in Dr. Greytak's report.

TABLE 1
Requirements for the S.B. Degree in Physics Beyond the General Institute Requirements

VIII

Required Subjects

8.03	Physics III (vibrations and waves)
18.03 or	
18.034	Differential Equations
8.033	Relativity
8.04	Quantum Mechanics I
8.044	Statistical Physics I
8.05	Quantum Mechanics II
8.06	Quantum Mechanics III
8.13	Experimental Physics I
8.14	Experimental Physics II
8.ThU	Thesis (12 units)

Restricted Electives

One math subject beyond 18.03
Two additional physics subjects, including one of the following:

8.07	Electromagnetism II
8.08	Statistical Physics II
8.09	Classical Mechanics II

VIII-B

Required Subjects

8.03	Physics III (vibrations and waves)
18.03 or	
18.034	Differential Equations
8.04	Quantum Mechanics I
8.044	Statistical Physics I
	One of the following subjects:
8.05	Quantum Mechanics II, *or*
8.033	Relativity, *or*
8.20	Introduction to Special Relativity
	One of the following experimental experiences:
8.13	Experimental Physics I, *or*
	a lab subject of similar intensity in another department, *or*
	an experimental research project/senior thesis, *or*
	an experimentally oriented summer externship

Restricted Electives

One additional physics subject
Three-subject focus group approved by Department

Figure 5.3 Graphic of the *requirements for focused and flexible physics majors at MIT.* Adapted from "An Educational Initiative: VIII-B in Review," by T. J. Greytak, 2003, *MIT Physics Annual 2003*, Cambridge, MA: Massachusetts Institute of Technology.

***TEAL format for introductory physics courses*.**

At around the same time as the flexible major option was introduced, several faculty members in the department were gearing up for a drastically new approach to teaching introductory physics, a studio approach that was championed by Dr. John Belcher, a MacVicar Faculty Fellow in the department of physics (MIT-4-INA; MIT-10-INA; MIT-17-JA; MIT-25-JA). This approach, Technology Enabled Active Learning (TEAL), pioneered by Jack Wilson and Karen Cummings and adapted from the Scale Up model developed by Robert Beichner at North Carolina State University, utilized technology in a state-of-the-art classroom to combine lectures, simulations, and hands-on experiments to engage students in collaborative learning.

According to several documents (MIT-JA-17; MIT-JA-25; MIT-27-IR; MIT-34-IKA), the first steps in implementing the TEAL initiative were to identify a location for the TEAL courses to be taught and then to renovate the room and equip it with various technological innovations to enhance learning. Once faculty and administrators decided on the physics reading room and completed the necessary renovations, two pilot studies were conducted in the fall of 2001 and 2002, followed by full-scale implementation in 2003 (MIT-6-CR; MIT-7-CAN; MIT-8-INA; MIT-18-CAN; MIT-21-PIT; MIT-25-JA; MIT-27-IR). Dr. Belcher described the premise of the TEAL approach and some of the specifics involved with implementing it.

> The basic idea of the studio classroom is to merge lecture, recitation, and hands-on laboratory experiments into a single common experience. Short intervals of formal instruction are interspersed with the desktop experiments (one experimental setup per group of three students) and collaborative work in groups.

The groups of three are formed at the beginning of the term and last throughout the term…A class meets for five hours per week in the TEAL/Studio (for example, two hours on Monday and Wednesday, and one hour on Friday)...For this initial effort, the staffing is somewhat higher than in steady state. Professor John Belcher, Dr. Peter Dourmashkin, Professor David Litster, and Dr. Alan Lazarus will teach these two sections [pilot sections] along with two graduate teaching assistants, technical instructors, and undergraduate help (MIT-06-CR).

In terms of pedagogy, Dr. Belcher described the ideal TEAL sequence in class, which began with instruction or lecture, followed by pre-experiment predictions, an experiment, and a visualization of the experiment (MIT-08-INA). Figures 5.4, 5.5, 5.6, and 5.7 are slides that Dr. Belcher used to illustrate this sequence in an industry article.

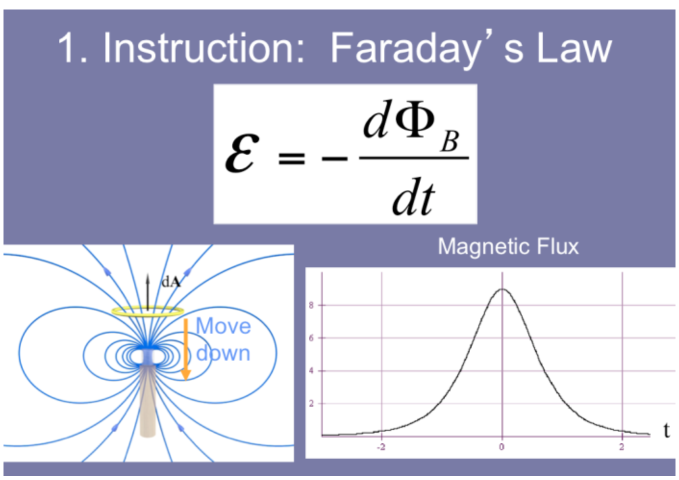

Figure 5.4 PowerPoint slide similar to what might be used in a TEAL classroom for the instruction part of the class. Adapted from "Introduction of the TEAL (Technology Enabled Active Learning) Format at MIT [PowerPoint Presentation], by J. W. Belcehr, 2008. Retrieved from http://sitresourcesworldbank.org/EDUCATION/Resources.

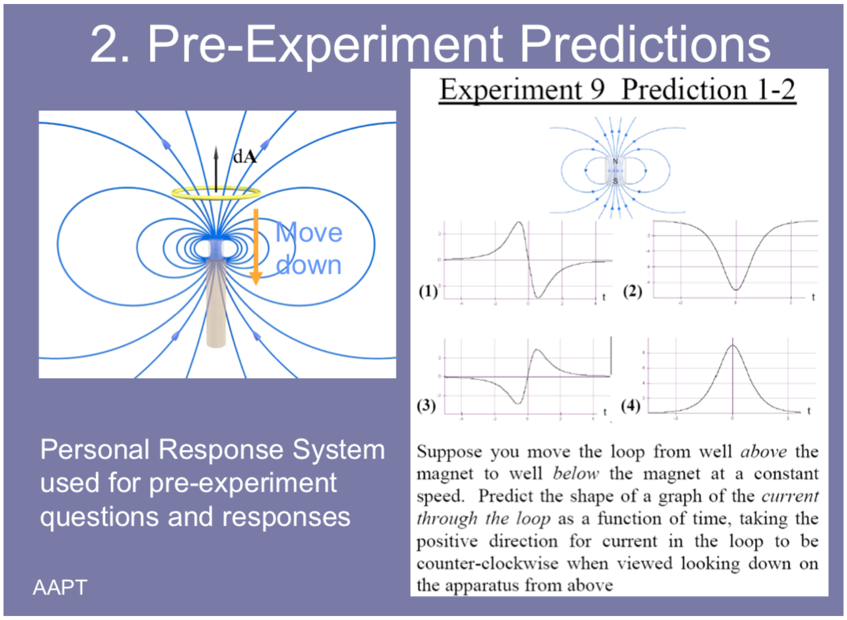

Figure 5.5 PowerPoint slide similar to what might be used in a TEAL classroom for the pre-experiment predictions. Adapted from "Introduction of the TEAL (Technology Enabled Active Learning) Format at MIT [PowerPoint Presentation], by J. W. Belcehr, 2008. Retrieved from http://sitresourcesworldbank.org/EDUCATION/Resources.

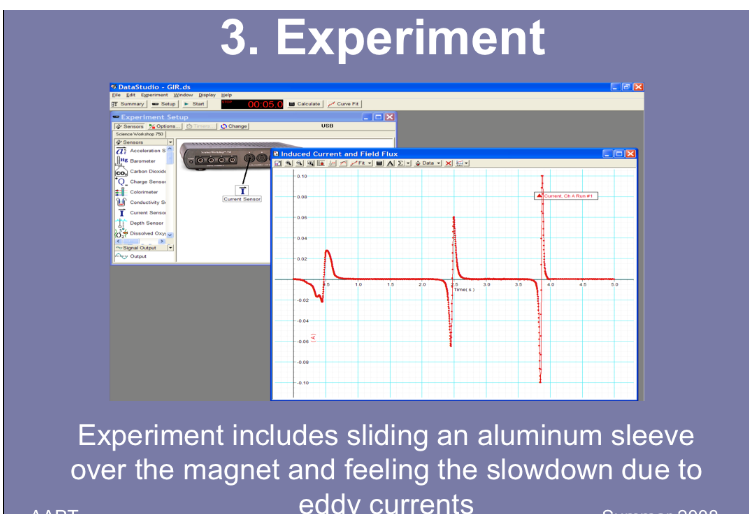

Figure 5.6 PowerPoint slide similar to what might be used in a TEAL classroom for the experiment in class. Adapted from "Introduction of the TEAL (Technology Enabled Active Learning) Format at MIT [PowerPoint Presentation], by J. W. Belcehr, 2008. Retrieved from http://sitresourcesworldbank.org/EDUCATION/Resources.

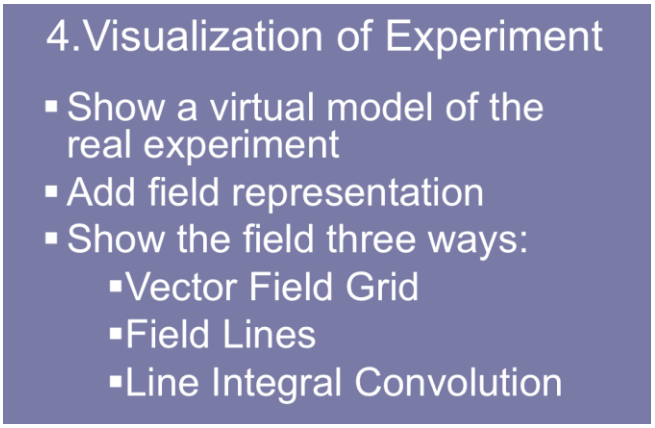

Figure 5.7 PowerPoint slide similar to what might be used in a TEAL classroom for the visualization of experiment. Adapted from "Introduction of the TEAL (Technology Enabled Active Learning) Format at MIT [PowerPoint Presentation], by J. W. Belcehr, 2008. Retrieved from http://sitresourcesworldbank.org/EDUCATION/Resources.

Other initiatives.

In addition to offering the flexible major option and utilizing the TEAL approach for teaching introductory physics classes, numerous documents reveal that faculty and administrators in the physics department also engaged in a number of other initiatives. These included encouraging student participation in Seminar XL and tutorial programs, both offered through the Office Of Minority Education (OME). The outside staff member interviewed for this study described Seminar XL.

> These [seminars] are small group-facilitated workshops, where students are taking math and science courses that are primarily first-year courses or what we call the General Institute Requirements. However, we do offer some second-year courses, as well. This workshop is not the recitation. Students come together in groups of 5 to 6 with a upperclassman or graduate student facilitator. They meet for about 90 minutes each week. The goal of these workshops is to help students learn critical concepts within the particular course, so they're working on problems and

> problem sets that are aligned with what's happening in the course and often even more challenging problems…Physics faculty are aware of this particular program, and they often recommend students for the program (MIT-23-PIT).

The staff participant in this study also indicated that the faculty also encourage students to participate in the tutorial programs offered to all students, not just physics students, through the OME. That staff member provided a brief overview of that service.

> The other program that students can take advantage of during the academic year is our Tutorial Services Room (TSR). Through the TSR, students have access to tutors at no cost to them. Students can make ad-hoc appointments, regular appointments, or they can participate in group-facilitated tutoring sessions. This differs from Seminar XL in that it is highly-focused on homework and exam preparation. This service is available to all students across all majors. Sometimes physics faculty will recommend physics students use the TSR, when they are unable to match them with a tutor in the physics department because they don't have one at the time (MIT-23-PIT).

The department also invited several diversity-related departmental reviews, including a Title IX review conducted by the NASA Office of Diversity and Equal Opportunity in 2007, after which the department was commended for its efforts to increase the participation of women, as detailed by Dr. Bertschinger, then chair of the physics department.

> The Title IX report concludes: "Based on an evaluation of the data provided by MIT and from on-site interviews and observations, NASA found the MIT Physics Department to be in compliance with the NASA Title IX regulations. NASA

notes with approval the extent and variety of promising practices MIT is undertaking in its efforts to increase the participation of women in its Physics Department and to ensure equal educational opportunity regardless of gender."…In particular NASA notes that MIT has very high numbers of women in its undergraduate physics program relative to other universities' physics programs (MIT-11-CNA).

Subsequently, the faculty followed the recommendations that came out of the Title IX review, as described by Dr. Bertschinger.

> The steps we have taken include affirmative action reviews of faculty and graduate student recruitment, paid maternity leave for graduate students and faculty, access to quality childcare, and automatic one-year delays in the faculty tenure clock for childbirth. Equally important are mentoring and support from faculty supervisors, department leaders, and fellow students (MIT-11-CNA).

Following Dr. Bertschinger's leadership, members of the department have also been supportive of the MIT Physics REFS Program, which is a team of eight graduate students trained in conflict mediation and tasked with providing confidential support to undergraduate physics students. They have also been supportive of the Institute Diversity Summit, which is an annual campus-wide summit on pertinent diversity issues. They have developed relationships with minority serving institutions (MSIs), such as Howard University, Southern University, University of Puerto Rico, Fisk University, Florida A&M University, Florida International University, University of Texas El Paso, Morehouse, and Spelman. Faculty also initiated a plan in 2009 to bring new talent from underrepresented groups, both faculty and students, to the department. In addition, the department invited a site visit from the APS Committee on the Status of Women in Physics and the Committee on Minorities to assess the department's efforts to be more inclusive (MIT-13-CR; MIT-98-INA). Each of these actions has been highly visible, and collectively the initiatives have had high accessibility for women and URMs, as evidenced by numerous articles and documents. A summary of findings related to high impact visible actions may be found in Appendix D on page 267.

Clear understanding and articulation of the rationale for change.

The numerous articles and other publications highlighting the success that the department of physics has achieved with regard to graduating women and URMs at rates higher than the national average are slightly misleading with regard to the impetus for these changes. For instance, an article in *Physics World* discussed the increases in undergraduates as if these increases were the result of an emphasis on diversity facilitated by Dr. Ed Bertschinger, chair of the department from 2008 to 2013.

> Since taking this role [as department head] in 2008, Bertschinger has spearheaded a series of initiatives to increase the diversity of people in the physics department – among students, researchers and faculty. As a result of these efforts, under-represented minorities now make up 17% of undergraduate students in the physics department at the MIT – a proportion that is significantly higher than the national average in the U.S (MIT-86-INA).

Although Dr. Bertschinger's contributions as department head played an instrumental role in focusing attention on diversity and excellence within the department, particularly with regard to graduate students, as indicated in numerous documents (MIT-11-CNA; MIT-12-CNA; MIT-13-CR; MIT-14-INA; MIT-20-CNA, MIT-22-PIT; MIT-23-PIT;

MIT-67-CNA), one initiative seemed to play a more pronounced role in the increases in enrollment and graduation of undergraduate females, and another potentially played a role. Both were implemented prior to Dr. Bertschinger's administration. Unlike many diversity initiatives that begin with a focus on underrepresented students groups, documents reveal that these initiatives began as the result of two separate circumstances that were evident in the larger population of students – a sharp decline in the number of physics majors and a track record for disproportionately high failure rates in freshman introductory physics courses, which are courses required of every student at MIT, not just those in the physics department.

The decline in the number of physics majors reaching a record low in 2000 was articulated as the impetus behind the introduction of the flexible major option, as noted in a report by associate department chair at that time, Dr. Thomas Greytak, in the *MIT Physics Annual* for 2003.

> As the last century came to a close, while others were concerned about Y2K, the Department was alarmed by the decreasing number of S.B. degrees in physics. The decrease was part of a nationwide trend, but the decline at MIT was more rapid than the average. During the 1980s, the number of S.B. degrees in physics at MIT had remained relatively constant at about 70. During the 1990s, however, the number of degrees decreased steadily, reaching a record low of 35 in 2000 (MIT-31-CR).

In addition to this sharp drop in the number of degrees, competition from Harvard was indicated as a contributing factor, as well. In the same report, Greytak noted, [w]hile examining the situation at other universities we learned that, contrary to the national trend, the number of undergraduate physics degrees at Harvard had been increasing and was then at about 50." The decline in undergraduate physics degrees at MIT was then attributed to the lack of flexibility in the physics major.

> We believed that the existing program provided our students with an unsurpassed preparation for graduate study in physics. However, upon reflection we realized that many students who were strongly attracted to physics had broader interests and would pursue other careers after graduation…The physics curriculum at Harvard had fewer specific requirements than ours. Approximately half of Harvard's physics majors went on to medical, law, or business school, or were pursuing other non-physics careers. AT MIT that fraction was only about a quarter" (MIT-31-CR).

This rationale prompted unanimous support among faculty for implementation of the flexible major option in 2000. "The flexible major has been widely uncontroversial almost since we introduced it," noted an administrator in the department during an interview for this study (MIT-22-PIT).

On another front, the high failure rate in freshman physics was articulated by one faculty member interviewed for this study as the overarching rationale for the TEAL initiative.

> What really motivated the change was the fact that physics was failing two to three times as many [students] as the other disciplines – math, biology, chemistry [required as part of the General Institute Requirements]. We would typically fail 10-15 percent, and they would typically fail 5 percent (MIT-21-PIT).

The collected documents consistently point to a threefold rationale that builds on the overarching rationale, an example of which is a summary in an edition of the *MIT Faculty Newsletter*.

> First, the traditional lecture/recitation format for teaching 8.01 and 8.02 [introductory physics courses] had had a 40-50% attendance rate, even with spectacularly good lecturers (e.g., Professor Walter Lewin), and a 10% or higher failure rate. Second, there have been a range of educational innovations in teaching freshman physics at universities other than MIT over the last few decades that demonstrate that any pedagogy using "interactive engagement" methods results in higher learning gains as compared to the traditional lecture format…Finally, the mainline introductory physics courses at MIT do not have a laboratory component. This is quite remarkable – to my knowledge MIT is the only major educational institution in the United States without a laboratory component in its mainline introductory physics courses (MIT-07-CNA).

Although these were the themes most consistently expressed with regard to rationale, several documents indicated that electromagnetism, one of the topics taught in introductory physics courses, is a particularly abstract and complex concept to teach by lecture, a circumstance that also prompted the TEAL approach (MIT-4-INA; MIT-6-CR; MIT-8-INA; MIT-17-JA; MIT-21-PIT; MIT-25-JA; MIT-26-JA).

Unlike with the flexible major initiative, there was not unanimous agreement in the department about whether TEAL was the most appropriate way to address the concerns expressed in the rationale. Regardless, the articulation of the rationale seemed to play an important role in establishing the initiative as a priority.

Complementing flexible major and TEAL initiatives a few years later was a specific emphasis on recruiting and retaining women and URMs spearheaded by Dr. Ed Bertschinger, who was department chair at that time. In an article he wrote for the *MIT Physics Annual 2012*, Dr. Bertschinger explained the rationale for this emphasis.

> When I came to MIT, the spirit among faculty and students seemed to be sink or swim; alumni from earlier years will recall speeches beginning, "Look to your left, look to your right." This approach seemed obviously flawed to me – after investing heavily in recruiting promising individuals, MIT (and other institutions) would fail to help people achieve their best. The result was poor morale leading to difficulty recruiting and retaining talented people (MIT-43-IKA).

Each of these reasons was referenced in numerous documents (MIT-6-CR; MIT-7-CNA; MIT-8-INA; MIT-9-INA; MIT-10-INA; MIT-17-JA; MIT-21-PIT; MIT-25-JA; MIT-26-JA; MIT-27-IR; MIT-31-CR; MIT-59-IIW; MIT-87-NA; MIT-90-NA). Additional findings related to understanding and articulating the rationale for change may be found in Appendix D on page 263.

Buy-In and advocacy from senior leadership.

One might assume that major initiatives like the flexible major option and TEAL would require consensus among the faculty before pursuing buy-in from senior leadership. Although documents suggest that there was consensus among faculty about the flexible major option, the decision to pursue both initiatives rested with the heads of the department. During an interview for this study, a faculty member described the processes related to decision-making in the department.

> Our processes within our department are a little bit opaque at times, and nothing at MIT is a democracy. Our process is not that we take votes. There are very few things at MIT that are decided by a vote of the department. The one exception is promotion to tenure; there is a vote. Promotion of a faculty member to a tenure position is something that a faculty votes on, but that's very rare (MIT-22-PIT).

This faculty member further noted that the decision to pursue both initiatives was that of Dr. Marc Kastner, who was the department chair at the time, and Dr. Tom Greytak, who was the associate chair of the department. "The decision to do TEAL was theirs. The decision to introduce the flexible program was theirs. They get credit or blame – in this case, credit" (MIT-22-PIT). In an interview for this study, another faculty member in the department also spoke of the decision-making process within the department.

> The MIT physics department department-head has a lot of power. This is a research university. The department head is not an honorary position. So basically he [Dr. Belcher, the champion of the TEAL initiative] went to the department head, and we have an associate head for education, and said he wanted to make this proposal to this institute funding mechanism. And that is what he wanted to do. And they agreed that he could do that…It was that easy because this was in the context of forty years of physics having a high failure rate (MIT-21-PIT).

The department heads supported Dr. Belcher throughout the implementation process, even though, as mentioned earlier, there was not always faculty buy-in. An administrator in the department, describing a particularly rocky moment during the TEAL implementation process, explained, "Tom and Marc decided to stay the course and make some improvements" (MIT-22-PIT).

When Dr. Bertschinger became chair, the support for additional initiatives that specifically targeted women and URMs intensified. Beyond supporting programs and initiatives offered through the Office of Minority Education, numerous documents suggest that he was personally invested in understanding the experiences of women and URMs – both students and faculty – within the department (MIT-11-CNA; MIT-12-CNA; MIT-13-CR; MIT-14-INA; MIT-20-CNA, MIT-22-PIT; MIT-23-PIT; MIT-67-CNA). In an interview for this study, one of the faculty members described this further.

> Ed's door was open to individual students with individual concerns. More than once you would have a situation where Ed, as department head, was the first to hear that some student had a need for such and such. Having a leadership that's open to the concerns of each student as an individual is very important (MIT-22-PIT).

The other faculty member interviewed for this study, also commented on Dr. Bertschinger's influence on the department, as well as on the indirect influence of the president of the institution.

> Well, I think that a lot of it [support] comes from the department head. As I said, the department head around here has a lot of power, and certainly when Ed was department chair it was clear to everybody that this [recruiting women and URMs] was important. I think the fact that MIT had a woman president changed the tenor of things, in terms of women (MIT-21-PIT).

Appendix D contains summary findings related to buy-in, starting on page 264.

Collaborative leadership at multiple levels.

Even though the department heads made the final decisions about which initiatives to implement in the department, these decisions were not made in isolation; rather, the chairs worked with various members of the department to ensure that their decisions were informed. A faculty member interviewed for this study explained this process.

> You have a group of colleagues, in this case called our education committee, which gathers information and opinions…We'll have a faculty lunch when we air out the concerns…We'll have a process of information gathering. We'll then have meetings of the education committee where we will discuss the options. At the end of the day, the education committee will make recommendations (MIT-22-PIT).

In a report in the MIT Physics Annual 2003, Dr. Greytak, former department chair, described the collaborative efforts involved with implementing the flexible major option. "It was a department wide effort involving the Education Committee, the Physics Council, and open meetings with both the students and the faculty," he noted.

TEAL also required faculty collaboration, although these collaborations were less visible at first. A faculty member in the department interviewed for this study explained.

> Well, we [faculty members enlisted by Dr. Belcher to work on TEAL implementation] did prototypes twice before we went large scale. And when we did the prototypes it was only with 150 students, and he [Dr. Belcher] was teaching it and another instructor here, not a physics faculty member – a very good teacher who was an instructor but not a faculty. His name is Peter

Dourmashkin, and he deserves ½ the credit for getting this done. The prototypes were very successful, but really basically nobody was paying attention to what we were doing (MIT-21-PIT).

In addition, the staff member interviewed for this study indicated that collaborations with the physics department were important to the success of the initiatives offered to physics majors.

> We have faculty who are liaisons to Seminar XL and to the Tutorial Services Room. We meet with the liaisons at least two or three times a semester in an advisory capacity; however, other faculty meet with the staff who run these respective programs as often as needed. For example, for Seminar XL, we are aligning the sessions with class content; therefore, we have to work with the faculty members and the TAs in those classes to ensure that our problem sets are actually aligned with what they're teaching – that we're following the syllabus just like they are (MIT-23-PIT).

Related findings may be found in Appendix D on page 265.

Planned attention to the environment for women and URMs.

It appears that the flexible major option provided an outlet for students to pursue their interest in physics in ways that were meaningful for them. This is in keeping with Maton's assertion that one aspect of creating an empowering setting is to develop programs that address the holistic needs of the students (2008). Dr. Greytak reported that the new VIII-B program

> was popular with the students from the start. We found that rather than using VIII-B to lighten their academic loads, students were constructing rigorous

> programs in a particular area that appealed to them…Students particularly appreciate the ability to use subjects from different departments, or even other universities, to achieve their goals (MIT-31-CR).

Greytak's report provided two examples of how women utilized the flexible option.

> A woman with a focus on science in Russia took EINSTEIN, OPPENHEIMER, FEYNMAN: PHYSICS IN THE 20TH CENTURY and SOVIET POLITICS AND SOCIETY 1917 – 1991 at MIT, and a Slavic language course at Harvard…One student crafted a focus in biological physics entirely from subjects in the biology department. I asked her if she was planning on getting a second degree. She said, "Yes, in math" (MIT-31-CR).

One of the faculty members interviewed for this study provided a more recent example of how a student used the flexible major.

> We have an alum, who was a student here a couple of years ago…, who put together a degree that was a physics degree but had a lot of economics and management in it. He's from the island of Mauritius and wants to go back to Mauritius and contribute to the economic development of Mauritius, but he loves physics…I think this person is going to be a future prime minister of Mauritius (MIT-22-PIT).

That female physics majors show an inclination toward flexible majors is consistent with the literature that says women may seek social relevance in the work that they do (Vaz, 2013; Wang, Eccles & Kenny, 2013) and therefore may appreciate the opportunity to craft a major that speaks to these interests.

Although the faculty in the physics department have not collected data to test this theory, there is evidence in the literature that women are also more attracted to and get more out of problem-based, interactive curricula than men (Brotman & Moore, 2008; Vaz, Quinn, Heinricher, & Rissmiller, 2013). So in addition to having more choice through the flexible major option, it is also possible that the TEAL format is more appealing to women and may encourage freshmen females in the introductory physics courses to consider majoring in physics. Additional summary findings related to planned attention to the environment for women and URMs may be found on Appendix D on page 266.

External Funding.

Without question, funding from two donors played a major role in the success of the TEAL format for teaching introductory physics courses. As a faculty member interviewed for this study noted,

> Around 2000, MIT got a lot of big donations from external sources. A fellow named Alex d'Arbeloff gave MIT $10 million and Bill Gates gave MIT $25 million. So there was a total of $35 million running around the Institute that was openly competed for by faculty (MIT-21-PIT).

Dr. Belcher, champion of the TEAL project at MIT, competed for funds and was awarded approximately $3 million. A faculty member noted, "first of all, he [Dr. Belcher] had a lot of money. He would never have been able to do this inside the physics department budget" (MIT-21-PIT). As discussed in an article in *Change Magazine*, transforming spaces to accommodate the TEAL approach was a large part of that expense.

> With support from the d'Arbeloff Fund, MIT transformed the former physics library into a 3,000-square foot classroom for TEAL. The classroom holds thirteen roundtables with nine students at each table…The instructor's "command center," from which he or she can control all the technology in the room, was purposely placed in the middle to move the faculty member from a position of authority at the front of the classroom. Numerous whiteboards and video screens around the perimeter of the room enable the students to see PowerPoint slides, visualizations, or demonstrations, no matter where they are sitting…The first TEAL classroom, which opened in fall 2001, cost approximately $1.5 million (MIT Document 80).

Figures 5.8, 5.9, 5.10 are photos of the TEAL classroom, as provided in one of the documents (MIT-05-IW).

Figure 5.8 Photo of an empty TEAL classroom to show the technology utilized in the introductory physics course. Adapted from "Adopters" [Wiki Page], Retrieved from http://spectrum.mit.edu/articles/teal-teaching.

Figure 5.9 Photo of an empty TEAL classroom to highlight the instructor's desk, which is not at the front of the room, but at the center. Adapted from "Adopters" [Wiki Page], Retrieved from http://spectrum.mit.edu/articles/teal-teaching.

Figure 5.10 Photo of a TEAL classroom during class time to illustrate the interactive nature of the introductory physics course. Adapted from "Adopters" [Wiki Page], Retrieved from http://spectrum.mit.edu/articles/teal-teaching.

In addition to the funds for the TEAL classrooms, Dr. Belcher also had enough funding through those grants and donations to develop the curriculum and to hire a visiting faculty member from the Department of Education in Technology and Science

Technion at the Israel Institute of Technology to conduct comprehensive assessment and evaluation of the TEAL classes (MIT-21-PIT; MIT-25-JA). A summary of findings related to external funding is in Appendix D on page 269.

Admissions Office.

One of the faculty members interviewed noted that the MIT Admissions Office played a major role in increasing the number of underrepresented students at MIT and, by consequence, in the physics department.

> In terms of why it is that we have a fair number of students from underrepresented groups graduating, I think part of it is that our admissions office provides us with the opportunity to teach this population…The MIT admissions office, in fact, gives us an undergraduate community that is, more so than many other places perhaps, well represented by historically underrepresented groups (MIT-22-PIT).

There seems to be merit to this assertion. A report to the president about admissions activity for the 2000-2001 academic year documents the pool of applicants.

> It was an extraordinary year for minority freshman admissions. We had a 19 percent increase in minority freshman applications, the highest on record at 887. This includes record high applications from African American and Mexican American students (MIT-42-CR).

A similar report to the president about admissions activity for the academic year 2003-2004, noted that

> [r]ecruitment efforts have been consolidated and reorganized. Under a director for recruitment, our recruitment team of four assistant directors and three

admissions counselors has increased outreach to minority populations, females, and academic superstars by 10 percent over previous years (MIT45-CR).

A report to the president in 2005 indicated staffing changes that diversified the admissions office staff to include increases in the number of African American and Hispanic admissions counselors (MIT-46-CR). The following two years, the admissions office reported a dramatic increase in URM enrollment "due to improved outreach, bringing more applicants to campus, and increased personal contact" (MIT-47-CR; MIT-48-CR). A 2007 article in the *MIT Faculty Newsletter* suggested that there had been a sustained effort to increase the number of underrepresented minorities. "The current proportion of underrepresented minorities at the undergraduate level at MIT is between 12% and 18%," the report detailed. "This is the result of a deep and sustained institutional commitment to increasing the diversity of the undergraduate student body" (MIT-93-CNA). These increases in enrollment, as reported by the admissions office at MIT, are summarized in Table 5.5 from the following documents: MIT-42-CR; MIT-43-CR; MIT-44-CR; MIT-45-CR; MIT-46-CR; MIT-47-CR; MIT-48-CR; MIT-49-CR; MIT-50-CR; MIT-51-CR; MIT-52-CR; MIT-53-CR.

Table 5.5

Percent Distribution of URMs and Females by Gender and URM Status

	2000 - 2001	2001 - 2002	2002 - 2003	2003 - 2004	2004 - 2005	2005 - 2006	2006 - 2007	2007 - 2008	2008 - 2009	2009 - 2010	2010 - 2011	2011 - 2012
Female	42	43	44	43	46	45	46	46	45	45	45	46
URM	18	16	17	17	14	21	22	25	24	23	24	24

Note. Adapted from *IPEDS Data Center*, National Center for Education Statistics (http://nces.ed.gov/ipeds/datacenter/)

A recent position announcement in admissions summarized the priority of enrolling underrepresented students that seems to have been prompted by these earlier efforts.

> The MIT Admissions Office seeks an assistant director [of admissions for minority recruitment] to independently plan, oversee, and manage recruitment programs with a focus on students of color and low-income applicants. Will work closely with the director of diversity and targeted outreach on short- and long-term strategic planning aimed at increasing the number of students of color and low-income applicants in the applicant pool (MIT-71-IIW).

A summary of findings related to the admissions office may be found in Appendix D on page 269.

Barriers.

Although the physics department has been successful in its efforts to increase the representation of women and URMs in the department, several documents reveal that this success was not without challenges, particularly with the TEAL initiative. One significant challenge was the backlash from students (MIT-17-JA; MIT-21-PIT; MIY-27-IR; MIT-28-CB; MIT-CNA-37; MIT-21-PIT; MIT-95-PB). According to an article in *The Tech*, the student newspaper online edition, students actually petitioned against TEAL.

> MIT has been quick to sing the praises of the Technology Enabled Active Learning version of 8.02, but more than 150 students are humming a different tune. A petition submitted to the physics department Wednesday asks MIT to halt the proposed expansion of the program, questioning its efficacy. The statement

reads: "8.02 TEAL does not provide us with the intellectual challenge and stimulation that can be expected from a course at MIT. We feel that the quality of our education has been compromised for the sake of 'trying something different.' We strongly advise that the traditional 8.02 course be reinstated as soon as possible. 8.02 TEAL could remain as an option, which will give TEAL an opportunity to evolve. However, it should not be forced upon the majority of the student body'" (MIT-37-CNA).

In addition to backlash from students, there was also an undercurrent of faculty who took offense to the TEAL format being touted as a better approach to teaching than a lecture-based format. One faculty member interviewed for this study explained the argument against the TEAL format.

> Many physicists think that the beauty of physics is that you start off with very few assumptions and one or two equations and then through logical derivation – with a lot of math – you go through an extended process, and you come up with a very impressive result. And the beauty of physics is to show the students this process, and you do that in a lecture where you spend 50 minutes developing the final result from the few initial assumptions (MIT-21-PIT).

Adding to this perspective was the celebrity of Dr. Walter Lewin, a professor in the department who had been praised nationally for his well-conceived and well-executed physics lectures. Biographical information about Dr. Lewin on the MIT website described his celebrity status.

> Lewin's lectures at MIT are legendary. Many have been shown for over six years (starting in 1995) on UWTV in Seattle, reaching an audience of about four million

> people…For fifteen years (starting in 1983) he was on MIT Cable TV helping freshmen with their weekly homework assignments. His programs, which were aired 24 hours per day, were also frequently watched by upper-class students. Additionally, his 35 lectures on Newtonian Mechanics, 36 lectures on Electricity and Magnetism and 23 lectures on Vibrations and Waves can also be viewed at MIT'S OpenCourseWare, iTunes U, YouTube and Academic Earth. Finally, seven special lectures for science teachers and for middle school students can be viewed on MIT World. These lectures are being watched by about 5000 people daily from all over the world, that's almost two million people per year!…Bill Gates wrote Professor Lewin that he has watched all his lectures more than once, and that he learned a lot from them (MIT-63-DIW).

There was some speculation that Dr. Lewin may have been the driving force behind the student petition. "Whether out of genuine concern for the students' education or out of fear that lectures would become passé," Breslow, author of an article in Change Magazine, explained, "this faculty member reportedly roused the students to the point that their dissatisfaction with TEAL became a public furor" (MIT-17-JA).

Assessment and evaluation of the TEAL-based instruction served to counter these two barriers. In an article in the *Journal of Learning Sciences*, Dori and Belcher summarized findings of a detailed assessment of the TEAL-format outcomes.

> Our study has established that the TEAL format has indeed had a significant and strong positive effect on the learning outcomes of MIT freshmen through technology-enabled active learning. The failure rate, a major trigger for the

> project has decreased substantially while the learning gains as measured by standard assessment instruments have almost doubled (MIT-25-JA).

Because of these findings, the department heads, as mentioned earlier, chose to "stay the course." An article in *Change Magazine* corroborates this support. "Kastner and Greytak supported Belcher and TEAL," Breslow, the author of the article, noted. "The dean for undergraduate education, Robert Redwine, met with unhappy students but maintained his support as well" (MIT-17-JA). A faculty member interviewed for this study observed that Dr. Belcher could always say that the students were learning twice as much, in spite of their displeasure. "If he [Dr. Belcher] had not been able to say that and justify that in a quantitative way, I think the whole thing would have died right there. So the assessment was absolutely crucial" (MIT-21-PIT). Subsequently, both faculty members interviewed for this study indicated that the issue of dissatisfaction among students and skepticism about whether the approach was effective among faculty were most prominent in the early stages of implementation. Since then student satisfaction in the TEAL courses is now at least where it was prior to the implementation of the TEAL format, and faculty are far less resistant (MIT-21-PIT; MIT-22-PIT).

Another challenge from the faculty perspective was that devoting time to teaching in the TEAL format was not necessarily an activity that would contribute to tenure. One of the faculty members interviewed for this study explained.

> This is a research university, so teaching formally in the classroom is not our prime purpose as for classroom teaching. Certainly education in a research context is a huge purpose, and we do it extremely well, but teaching in a freshman physics context is not what we tenure faculty for, so we always have to deal with

> the fact that these faculty are under a lot of pressure to do other things (MIT21-PIT).

In response to this barrier, the same faculty member described the attention given to simplifying the time faculty had to devote to course preparation.

> For one thing, they [the course administrators] make it really easy for them [instructors] to teach in this format, so it's not like they have to put together the course from scratch. So they write the problem sets. The course administrators do the problem sets. They do the exams. They organize graders. They do everything. The faculty member has to be familiar with the material and walk in and be interactive with the students. That, in fact, is a pleasure…and a lot of the faculty really just enjoy the experience of teaching in this format (MIT-21-PIT).

Appendix D contains a summary of findings related to barriers, starting on page 270.

> The review of documents in this case facilitated a better understanding of the various strategies utilized by faculty and administrators to impact the success of women and URMs, even though many of these strategies did not involve an intentional focus on these underrepresented populations. Additionally, the documents revealed the barriers that faculty and administrators faced with implementing initiatives in the department, and the strategies they used to overcome the obstacles. A complete summary of findings may be found in Appendix D on page 263.

CHAPTER 6
University of Texas at Austin – Cockrell School of Engineering

At the Cockrell School of Engineering, we believe diversity in the workplace and the learning space enriches the environment for all. Workplace diversity improves business' need to serve a broad customer base and spurs innovation. Classroom diversity fosters respect for new ways of thinking and learning and prepares students for the global community where they will live and work. – Cockrell School of Engineering (UT Austin, Cockrell School of Enginering, 2014)

University Profile

Founded in 1883, the University of Texas Austin (UT-Austin), classified by Carnegie (2013) as a research university with very high research activity (RU/VH), is one of the largest public research institutions in the United States and the largest in the University of Texas system. Its graduate school is also one of the largest graduate schools in the nation (UT-Austin, Campus Profiles, 2014). The University has 17 colleges and schools housed on 350 acres and several satellite campuses and research centers located throughout Texas, including the J.J. Pickle Research Campus, the Marine Science Institute, the McDonald Observatory, the Montopolis Research Center, and the Brackenridge tract. "An enduring symbol of the spirit of Texas — big, ambitious and bold," staff note on the website, "the university drives economic and social progress in Texas and serves our nation as a leading center of knowledge and creativity." It offers over 170 fields of study and 100 majors and has eighteen colleges and schools, including the Cockrell School of Engineering, the College of Education, the College of Fine Arts, the College of Liberal Arts, the College of Natural Sciences, the College of Pharmacy, the Dell Medical School, the Graduate School, the Jackson School of Geosciences, the

Lyndon B. Johnson School of Pubic Affairs, the McCombs School of Business, the Moody College of Communication, the School of Architecture, the School of Information, the School of Law, the School of Nursing, the School of Social Work, and the School of Undergraduate Studies.

During the 2013-2014 academic year, the University enrolled 39,979 undergraduate students and 12,080 graduate students for a total of 52,059 students (UT-Austin, 2014). Females comprised 50.7 percent of the total student population. In terms of ethnic diversity, White students comprised 47.7 percent of the total population, followed by Hispanic students at 21.7 percent, Asian students at 17.8 percent, Non-Resident Alien students at 4.7 percent, Black students at 4.3 percent, and Two or More Race students at 3.1. American Indian/Alaska Native students, Native Hawaiian/Pacific Islander students, and Unknown Race students each comprised less than 1 percent of the student population. With a freshman admission acceptance rate of 40.2 percent, 75.3 percent were in the top ten percent of their high school classes, and all of the SAT scores of freshmen in the 25th percentile were above 550, with the highest scores in math (UT-Austin, 2014).

UT-Austin employed 3,035 faculty during the 2013-2014 academic year, which allowed for a student ratio of 18 to 1. Of all faculty, 88.2 percent held a doctorate or the highest degree in their respective fields. The faculty have received numerous honors and recognition over the years. Among them, three were Nobel Prize winners, two received the A.M. Turing Award, five were named MacArthur Fellows, five received the National Medal of Science, three were recognized as Pew Scholars, three received the Pulitzer Prize, three received the Wolf Prize, three received the National Medal of Technology and Innovation, and fifty-one were recognized as American Academy of Arts and Sciences Fellows, among numerous other honors (UT-Austin, 2014).

With tuition at $9,798 and room and board at $11,362, nearly 41.1 percent of students received some form of financial aid up to $12,427. The University had an operating budget of $2,279,183,295 and an endowment of $2,861,389,483 in 2012 (U.S. News and World Report, 2014). Table 6.1 provides a brief profile of the University.

Table 6.1

University of Texas Brief Profile: 2013-2014 (UT-Austin, 2014)

Area of Interest	**Description**
Undergraduate Enrollment:	39,979
Graduate Enrollment:	12,080
Gender Ratio Undergraduate:	50.7 percent
Gender Ratio Graduate:	31 percent
Ethnic Distribution (Undergraduate):	American Indian/Alaskan Native – < 1 percent Asian American – 17.8 percent Black/African American – 4.3percent Hispanic/Latino – 21.7 percent Native Hawaiian/Pacific Islander – <1 percent Non-Resident Alien – 4.7 percent Race Not Indicated – < 1 percent Two or More Races – 3.1 percent White/Caucasian – 47.7 percent
Admissions Acceptance Rate:	40.2 percent
Freshman Class:	75.3 percent in top 10 percent of class
Freshman SAT Scores: (Range includes scores at the 25th and 75th percentile)	SAT Critical Reading: 550 – 670 SAT Math: 590 – 710 SAT Writing: 550 – 680
Freshman ACT Composite	25 – 31 (based on 25th and 75th percentile)
Distribution of Declared Engineering Majors	Undergraduate – percent Graduate – percent
Student-to-faculty ratio:	18:1
Students living on campus:	18.4 percent
Faculty	2752 Full-time; 283 Part-Time; Total 3,035 88.2 percent hold Ph.D. or highest degree in field
Female Faculty	38.5 percent
Minority Faculty	19.8 percent
Tuition:	$9,798 (Undergraduate)
Room and board:	$11,362 (Undergraduate)
Financial Aid	41.1 percent received some financial aid up to $12,427
Average starting salary for engineering graduates (2013):	$71,039 (for students with bachelor's degree)
Endowment (2012):	$2,861,389,483
Annual operating budget:	$2,279,183,295

Note. Adapted from "Campus Profile," UT-Austin (http://www.utexas.edu/about-ut/campusprofile), "The University of Texas System: Operating Budget Summaries – Fiscal Year 2013, University of Texas System, 2013 (http://www.utsystem.edu/cont/reports_publications/summaries/2013/FY2013Budget Summaries.pdf), and "University of Texas—Austin," U. S. News and World Report, 2014 (http://colleges.usnews.rankingsandreviews.com/best-colleges/university-of-texas-austin-3658.

Cockrell School of Engineering

The Cockrell School of Engineering (CSE) was established at UT-Austin in 1882. Since that time, it has become the most popular of the STEM discipline majors and the third most popular major (11.9 percent) at the University behind Communications/ Journalism (12.2 percent) and Social Sciences (12.2 percent)(NCES, 2014). CSE offers degrees in nine program areas – biomedical engineering, chemical engineering, civil engineering, computer engineering, electrical/electronic engineering, environmental engineering, mechanical engineering, and petroleum engineering – and employs 280 tenure or tenure-track faculty, 680 staff, and over 1,900 student employees (UT-Austin, Cockrell School of Engineering, 2014). The School boasts 137 endowed chairs and professorships for faculty and the fourth highest membership in the American Society for Engineering Education among senior faculty. In addition to these honors, the faculty includes 49 members of the National Academy of Engineering, and 63 junior faculty have received Faculty Early Career Development awards from the National Science Foundation. Table 6.2 provides more information about CSE as it compared to other colleges and schools at the University.

Table 6.2

Brief overview of departments at UT-Austin: 2013-2014

Department	**Number of Faculty and Staff**	**Departments, Programs, & Centers**	**Percent Distribution of Students**
Cockrell School of Engineering	280 Faculty	7 departments	11.9
College of Natural Sciences	377 Faculty	11 academic departments	Biology- 11.9 Mathematics – 2.6 Phy. Sciences – 2.8
McCombs School of Business	181 Faculty	6 departments	11.8
Moody College of Communication	174 Faculty	5 departments	12.2
School of Architecture	103 Faculty	8 programs	.7

Note. Adapted from "Colleges and Schools," UT-Austin, 2014 and IPEDS Data Center, National Center for Education Statistics (http://nces.ed.gov/ipeds/datacenter/)

CSE ranked third on Diverse Issues' (2013) list of top 100 degree producers for minority students in engineering and ninth on ASEE's list for awarding bachelor's degrees in engineering to women (Yoder, 2012). With regard to these underrepresented student populations, it has seen the most growth among female students – with 136 degree completions in 1999 and 115 in 2011 – and Hispanic students – with 83 in 1999 and 115 in 2011. The School has not has had as much success with African American students, American Indian/Alaska Native students, and Native Hawaiian/Other Pacific Islander students. However, it enrolls a larger percentage of bachelor's degrees to African American students than other top-ranking public institutions (UT-Austin, Cockrell School of Engineering, 2014). Table 6.3, Figure 6.1, and Figure 6.2 provide additional information about degree completions in CSE by gender and ethnicity.

Table 6.3

Engineering Degree Completions by Gender and Ethnicity

	1998-1999		2000-2001		2002-2003		2004-2005		2006-2007		2008-2009		2010-2011	
	#	%	#	%	#	%	#	%	#	%	#	%	#	%
Male	595	81.4	583	78.5	649	76.2	667	77.6	723	75.5	746	78.2	811	78.7
Female	136	18.6	160	21.5	203	23.8	193	22.4	234	24.5	208	21.8	219	21.3
AIAN	2	0.3	2	0.3	3	0.4	4	0.5	4	0.4	3	0.3	4	0.4
Asian	136	18.6	171	23.0	220	25.8	201	23.4	244	25.5	212	22.2	245	23.8
BAA	26	3.6	23	3.1	18	2.1	23	2.7	20	2.1	12	1.3	25	2.4
H/L	83	11.4	87	11.7	89	10.4	95	11.0	107	11.2	135	14.2	115	11.2
NHOPI*	-	-	-	-	-	-	-	-	-	-	-	-	0	0.0
NRA	57	7.8	57	7.7	55	6.5	80	9.3	54	5.6	77	8.1	90	8.7
RU	0	0.0	2	0.3	1	0.1	3	.3	5	0.5	5	0.5	3	0.3
TMR*	-	-	-	-	-	-	-	-	-	-	-	-	4	0.4
White	427	58.4	401	54.0	466	54.7	454	52.8	523	54.6	510	53.5	544	52.8

Note. Bold line indicates the year of the first graduating class after introduction of WEP FIGs. AIAN = American Indian/Alaska Native. BAA = Black/African American. H/L = Hispanic/Latino. NHOPI = Native Hawaiian or Other Pacific Islander. NRA = Non-Resident Alien. RU = Race Unknown. TMR = Two or More Races. NCES did not separate out NHOPI and TMR prior to 2010-2011.

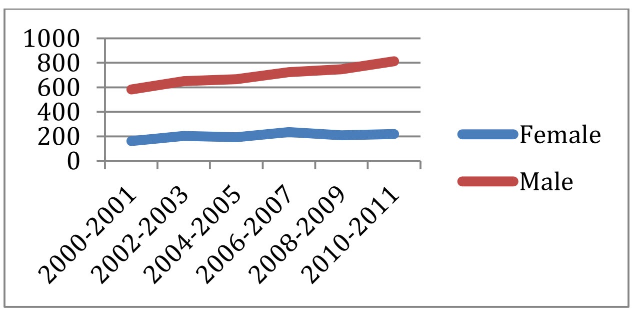

Figure 6.1 Chart illustrating engineering degree completions at UT-Austin by gender. Adapted from IPEDS Data Center, National Center for Education Statistics (http://nces.ed.gov/ ipeds/datacenter/).

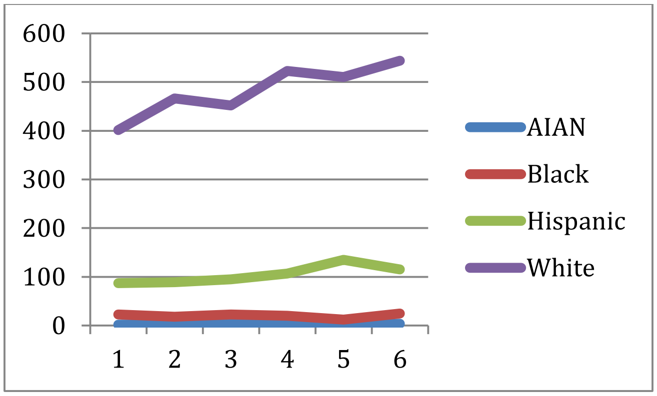

Figure 6.2 Chart illustrating engineering degree completions at UT-Austin by ethnicity. Adapted from IPEDS Data Center, National Center for Education Statistics (http://nces.ed.gov/ ipeds/datacenter/).

Document Collection Overview

To facilitate an understanding of the strategies that faculty and administrators in CSE utilized to increase the graduation rates of women and URMs, 72 documents were collected, reviewed, and analyzed. These documents provided insight from multiple perspectives and included conference papers, journal articles, college reports, and industry news articles, as well as other types of documents.

The primary sources of information, that is, information collected from people directly involved with the implementation of the various initiatives associated with the increase in female and URM students and/or directly involved with the current facilitation of these initiatives, included the transcripts from interviews conducted by the researcher with one faculty member and two staff members in the department. (To ensure an interview environment in which these individuals felt comfortable sharing their candid perceptions of the processes involved with implementing the initiatives in the physics department, they were each interviewed with the understanding that their identities would not be revealed.) Additional primary sources included journal articles, which documented much of the implementation process. Most of these were written by faculty and administrators who were directly involved with the initiatives in the CSE, including Andrea Ogilvie and Carrie Schade. Other primary sources included college reports, grant information, and state government reports. Each of these provided insight into the processes involved with program implementation.

The secondary sources – college news articles, industry reports, news articles, etc. – were also helpful, as many of them contained information obtained from interviews with the faculty and staff closely associated with the initiatives in the department or from awards the department received as a result of their efforts. The various angles from which the authors framed their discussions provided details that, in some cases, were not provided in the documents from primary sources. These sources also helped the researcher track the various activities with which those close to the initiatives were involved. In addition, these documents included outside perspectives that helped to frame the initiatives within the broader context of the engineering community.

Each document was assigned an ID based on the institution (MIT) and the type of document, and this number is referenced in the discussion of findings. Table 6.4 provides a detailed listing of the document types, the abbreviations for the document types, and the number of documents collected in each category. The complete listing of documents is on page 243 of Appendix A.

Table 6.4

Documents Collected for UT-Austin

Document Type	Abbreviation	# of Document
College Information on Website	CIW	18
College News Article	CNA	5
Conference Paper	CP	3
College Report	CR	8
External College Review Site	ECRS	1
External Organization Website	EOW	2
External Report	ER	1
Grant Information	GI	1
Industry Report	IR	1
LinkedIn	LI	1
News Article	NA	5
Participant Interview Transcript	PIT	2
State Government Website	SGW	4
University Dissertation	UD	1
University Information on Website	UIW	5
University Minutes	UM	2
University News Article	UNA	7
University Report	UR	6
Total		72

Findings

There are two major program areas in the student affairs division of the Cockrell School of Engineering with goals and missions that are directly tied to increasing the retention and graduation rates of minorities and women – the Equal Opportunity in Engineering (EOE) program formed in 1970 and the Women in Engineering Program (WEP) formed in 1991 (UTA-55-CIW). Through the years, these program areas have offered a wide range of programs, activities, and services to underrepresented students, including, academic, social, and psychological support (UTA-07-PIT; UTA-08-PIT; UTA-47-CIW; UTA-50-CIW; UTA-63-CIW; UTA-65-CIW; UTA-68-CIW). Unlike many other such program areas at other institutions, these program areas are externally funded, which as one administrator described is a "mixed blessing" (UTA-08-PIT). As determined from reviewing collected documents, this surprising departure from the norm largely drove the strategies that EOE and WEP utilized to "institutionalize" their most successful programs. As a result, high impact visible actions staged over time, articulating the rationale for change, planned attention to the environment for women and URMs, and assessment and evaluation were critical to the implementation and subsequent success of these programs. In addition to strategies from the Transformational Change Model for Inclusive Excellence, Texas public policy and University of Texas system policies also played a role in transforming the student culture in CSE.

External funding.

Although many institutions depend on external funding to supplement the programming funds allocated to diversity and inclusion initiatives, very few rely on external funding for the operations of an entire program area. With the exception of the program director salaries, the budget for operations in EOE and WEP is solely determined by fundraising efforts, as is described by a staff member interviewed for this study.

> When we talk to some of our peers, for example, most program staff are funded. At least the director and another person are funded by the university. The salary of the program director is covered, and that's it. When we say we have to pay for all of our IT and all of our computers and all that kind of stuff, that's different from other models where that is part of their department or institutional funding (UTA-08-PIT).

Additionally, neither program has a dedicated development officer assigned through the University, as the staff member further explained.

> We have the support, but we don't have, like the departments do, a dedicated development person who's going out there fundraising for student programs…They [School administrators] have development officers help us with different things, but the assumption is that we're taking care of it ourselves (UTA-08-PIT).

In spite of this funding model, or perhaps because of it, the staff in EOE and WEP have raised enough funds to maintain a supporting staff of three, in addition to the directors who are funded through the University/School. One staff member described fundraising efforts.

> We've learned how to build great relationships with companies that bring in the role models and bring in the funding. We've been able to steadily maintain, if not grow, what that funding base looks like. I think having the name of the University of Texas at Austin behind us doesn't hurt in that respect. People know who we are. We are a known commodity, so they come in and support us (UTA-08-PIT).

In both programs, funding is achieved through partners who donate at various giving levels. As deduced from the web pages of both programs, during the 2012-2013 academic year, staff members in EOE raised a minimum of $250,000 (UTA-56-CIW; UTA-57-CIW), and staff members in WEP raised a minimum of $202,000 (UTA-66-CIW; UTA-64-CIW). Corporate and private partners at the highest levels included Baker Hughes, Bechtel, BP, Boeing, Caterpillar, Central Intelligence Agency, Chevron,

Chevron Phillips, ConocoPhilips, Dow, ExxonMobil, Fluor, Friends of Alex!, GM, Halliburton, Marathon Oil, NSF, Semiconductor Research Corporation, Schlumberger, Shell, Texas Instruments, and the Texas Workforce Commission. Figure 6.5 shows the number of partners for each program by giving levels.

Table 6.5

Partners at Various Giving Levels: 2012-2013

Giving Level	**Number of Partners - EOE**	**Number of Partners - WEP**
Platinum ($25,000 or more)	4	2
Gold ($15,000 to $24,999)	3	4
Silver ($10,000 to $14,999)	7	4
Bronze ($5,000 to $9,999)	6	3
Friend ($1,000 to $4,999)	5	37
Total	25	50

Note. Adapted from "Our Partners: EOE Partners for Academic Excellence – 2012-2013 Partners," Cockrell School of Engineering, Equal Opportunity in Engineering Program (http://www.engr.utexas.edu /eoe/partners) and "Our Partners," Cockrell School of Engineering, Women in Engineering Program (http://www.engr.utexas.edu/wep/partners)

As mentioned previously fundraising efforts drive staff salaries, as well as activities and services offered through the programs. In 2007, for instance, it was estimated that the cost per year to cover EOE FIG expenses was $30,000, including 20 percent of work time from the program coordinator, 15 percent of work time from seminar facilitators, three hours per week for eight peer leaders each week for the fall and spring semesters, and four hours per week allocated for FIG academic tutors (UTA-17-CP).

One might assume that having such a funding model for programs the stature of EOE and WEP might be detrimental to the goals and missions of these programs. To the contrary, the manner of funding actually shields the programs from certain circumstances that can hinder similar program offices at other universities. One staff member explained.

> It's kind of a mixed blessing. I won't say that I don't like it because when there are budget cuts across the university, it does not impact us. We can keep doing what we're doing, and we don't have to answer to anybody else on what we're doing and why we're doing it…So I'm actually okay, in some respects, with the funding model because we don't have to follow everybody else's rules (UTA-08-PIT).

As a result of having a different set of rules, the approaches and strategies for implementing the FIGs and other initiatives varied greatly from those utilized by programs with more traditional funding models. However, these approaches still fit within the Transformational Change Model for Inclusive Excellence. A summary of findings related to external funding may be found in Appendix E on page 279.

High impact visible actions staged over time.

Documents reveal that there have been numerous programs and initiatives designed to increase the retention and graduation of women and minority students long before the initiatives that are highlighted in this study. Just before 2000, however, there were a number of initiatives that emerged and that are credited with the gains CSE has made with enrolling and graduating women and URMs since 2000.

WEP First Year Interest Groups.

According to a dissertation reviewed for this study (UTA-01-UD), First Year Interest Groups, commonly referred to as FIGs, are learning communities that allow students to register as a cohort for two or three classes and often include one seminar class that provides an opportunity for students to reflect on the subject matter from each of the classes they share. These learning communities, successfully modeled by universities in Washington, Oregon, and Missouri, integrate student collaboration, faculty collaboration, curricular coordination, and a shared setting. Alvarado, the author of the dissertation indicated that the FIG program at UT-Austin emerged in the late 1990s in response to concerns that administrators had about the quality of the undergraduate experience. She described this concern in detail.

> The impetus to develop the FIG program evolved from a growing concern for improving the undergraduate experience. The University of Texas at Austin was fighting a public perception that students were just numbers at the institution. The Office of the Vice President for Student Affairs decided to initiate the program to improve the first-year experience of students at the University, both inside and outside of the classroom (UTA-01-UD)

As noted in the dissertation, several FIG communities in many disciplines were piloted in 1998, one of which was an engineering FIG offered through WEP. Schade shared information about the first offerings.

> The four FIGs (one each year for the past four years) run by the Women in Engineering Program have been based on varying models and have included some or all of the following aspects: weekly one-hour seminars, co-enrollment in basic sequence courses, a residential component, assorted advisors and peer mentors, and out-of-class activities. The seminars are conducted by the FIG advisor and peer mentor and include educational, social, and developmental aspects (UTA-22-UR).

According to Schade, the courses in which students enrolled as a cohort in 1998 and 1999 included Differential and Integral Calculus and Principles of Chemistry I. In 2000, the courses in which students enrolled as a cohort included either Differential and Integral Calculus; Sequences, Series, and Multivariable Calculus; or Multivariable Calculus, depending on individual placement; and Principles of Chemistry I. The FIG emphasis in 2001 changed to a residential model that did not involve course co-enrollment. Instead, students lived together on a floor in the honors residence hall (UTA-22-UR). Currently, the WEP program offers four FIGs, the Architectural and Civil Engineering FIG, the All About ME FIG (mechanical engineering), the Rockin' Pipettes FIG (chemical and petroleum engineering), and the Fabulous Intelligent Gals FIG (biomedical, aerospace, electrical and computer engineering) (UTA-63-CIW). According to a staff member interviewed for this study, the course offerings change periodically to accommodate the needs of the students (UTA-08-PIT).

Graduates Linked with Undergraduates in Engineering program.

In addition to the WEP FIGs, which are credited in many of the collected documents as having contributed to the number of female graduates in engineering, one staff member interviewed for this study also indicated that the Graduates Linked with Undergraduates in Engineering (GLUE) program has also contributed to the retention of females. This program, which was piloted in 2001, provides female undergraduates with research opportunities by pairing them with graduate students in their majors. According to the staff member, a CSE faculty member who had been associated with a similar program at UC Davis first approached the staff in WEP about what would later become known as GLUE.

> She [the faculty member] approached us wanting to look at establishing some sort of undergrad research program based on that same model – here focused on our female students – and she wrote it up as part of her career grant, which she ended up receiving. We started it in collaboration with her, and she's still involved in the program. It's grown since then. We started it with maybe 11 or 12 students in the first class that we piloted, but now we run it each spring semester with around 25 students. This next year we're actually piloting another one in the fall. We actually will run it fall and spring to see if it's doable (UTA-08-PIT).

A document detailing WEP programs and activities provided additional details about the GLUE program.

> Undergraduate students assist with research projects and participate in a weekly seminar class where students share their research experiences, learn about research options in industry and academia, hear from panels of graduate students and engineers, and learn about graduate school and other undergraduate research options (UTA-63-CIW).

During the 2013-2014 academic year, twenty-four second and third year engineering women were paired with twenty-four masters and doctoral engineering students.

Other WEP programs.

In addition to these other programs that were established in the early 2000s, one staff member interviewed for this study credits an earlier initiative with increasing the number of female engineering graduates. According to this staff member, this program is the First Year Initiative (FYI) program. A document describing WEP initiatives provides details about the scope of this program

> The First Year Initiative (FYI) is designed to increase the retention rate of first year female engineering students into their second year. FYI events provide academic and peer support to inform students about engineering as a major and to connect students to the engineering community and the resources available to them. As part of FYI, first year women are matched with Peer Assistance Leaders (PALs), undergraduate mentors in their majors, who help answer questions about being an engineering student and maintain communications throughout the fall and spring semesters (UTA-63-CIW).

This program is offered to students as part of numerous other program offerings grouped in the WEP Retention and Academic Success Initiatives, including the Kinsloving Learning Community, a residential learning community for first-year engineering students, and the Women in their Second year of Engineering (WISE) program, a program designed to assist female engineering students as they make important major and career choices (UTA-63-CIW).

***EOE First Year Interest Groups*.**

In 2000, the EOE developed a diversity and outreach plan designed to enroll and retain URMs in the school of engineering (UTA-41-CR). A key component of the program was the implementation of FIGs, which were comprised of 20-25 students who were "enveloped in a web of support" that included mentoring, tutoring, and networking among peers, upperclassmen, and faculty (UTA-17-CP). Two FIGs were piloted in 2000 and then doubled in 2003. Ogilvie provided an overview of this program in a conference paper.

> The participants in each FIG cohort share a common class schedule that includes three to four basic sequence courses in the engineering degree plan…One of these courses is a small, one-hour weekly seminar where students can get to know each other. Led by Peer Leaders, Academic Tutors, and EOE staff members, the FIG seminar is designed to help students improve study skills and develop strategies for academic success (UTA-17-CP).

From 2003 to 2007 in both the fall and spring semesters, the FIG course offerings, according to Ogilvie (UTA-17-CP) included the following: 1) The Achievers (electrical and computer engineering), with co-enrollments in Calculus I, Intro to Electrical Engineering, Intro to Computing, and the FIG seminar; 2) The Visionaries (mechanical engineering), with co-enrollments in Calculus I, Chemistry I, Intro to Mechanical Engineering, and the FIG seminar; 3) Strength in Numbers (aerospace and civil engineering emphasis), with co-enrollments in Calculus I, Chemistry I, and the FIG seminar; and 4) Infinite Momentum (all engineering majors except electrical engineering), with co-enrollments in Calculus I or Calculus II, Chemistry I, and the FIG seminar.

In 2007, the courses expanded to include the following: 1) The Innovators (interdisciplinary emphasis) with co-enrollment in the FIG seminar and 2) Infinite Momentum B (electrical & computer engineering emphasis, with co-enrollments in Calculus I, Intro to Electrical Engineering, Intro to Computing, and the FIG seminar (UTA-18-CP). Current FIG offerings include the Achievers (electrical engineering), Infinite Momentum (multidisciplinary), The Visionaries (mechanical), Strength in Numbers (civil, architectural and aerospace).

Largely because of the FIG initiative, Exxon Mobil Corporation and the National Society of Black Engineers (NSBE) awarded the Cockrell School of Engineering's EOE program a $10,000 competitive grant, the only one awarded out of 17 programs at various institutions. Franklin Moore, the director of programs for NSBE, explained why the two organizations chose UT-Austin.

> The goal of this award is to find a successful program that's easy to replicate at any university. From the African American perspective, we only have a 30 percent retention rate nationally [for students finishing four-year engineering degrees] and that's horrible. Programs like EOE at The University of Texas at Austin are so important because they help us keep our underrepresented engineering students in engineering, and the ones who like it will succeed (UTA-41-CR).

Other EOE initiatives.

Another key component of the EOE's strategic plan mentioned earlier included three program opportunities for rigorous research that were in place prior to 2000 – the Texas Research Experience (TREX) that engaged students in research opportunities in exchange for research stipends; the L-SAMP Summer Research Alliance, which provided a preview of the types of research experiences students could expect in graduate programs; and the Summer Research Academy (SRA), offered to students with a minimum of a 3.0 GPA.

In addition, EOE and WEP offered numerous other programs as well, including several pre-college programs, such as the My Introduction to Engineering (MITE) summer camp for high school juniors; the Longhorn Engineering: The Power to Shape

Your World, a free campus tour of engineering facilities and labs for URMs and economically challenged high school students; and EOE GuideRight, a special preparatory/orientation program for high school students who have been accepted to UT-Austin. Combined, these activities have produced graduation rates for women and URMs that are well above the national average. A summary of findings about these high impact visible actions may be found in Appendix E on page 276.

Clear understanding and articulation of the rationale for change.

Based on the documents reviewed for this study, there were two underlying circumstances that prompted the EOE and WEP initiatives described in this study: 1) there was a gap in retention rates between minority and non-minority and male and female students in CSE (UTA-04-ER; UTA-17-CP; UTA-18-CP) and 2) a large percentage of African American, Hispanic, Native American, and female students had limited exposure to strategies and resources for academic success (UTA-04-ER; UTA-07-PIT; UTA-17-CP; UTA-18-CP; UTA-22-UR).

The articulation of these two circumstances as the rationale for the initiatives in the department by staff in EOE and WEP seemed primarily geared toward fundraising efforts and student recruitment. In terms of fundraising, both programs have websites devoted to corporate partners, and both provide great detail about the programs and services. To address these circumstances, EOE, as noted in one of its promotional documents, utilized the research to guide programming efforts. This promotional document described the approach that guides academic initiatives.

Guiding principle is based on Alexander Astin's article *Involvement: The Cornerstone of Excellence*. "Excellence in education is directly related to student involvement as measured by five indicators:

1. Time and energy devoted to studying
2. Time spent on campus
3. Participation in student organizations
4. Interaction with faculty
5. Interactions with other students" (UTA-61-CIW)

The document also detailed the approach that guides leadership and professional development initiatives.

Guiding principle is based on Ray Landis's article, Retention by Design. "Promote a high level of collaborative learning among the student community to achieve positive outcomes such as improved academic performance, improved retention, enhanced student satisfaction with the learning experience, improved oral communication skills, and higher student self-esteem." (UTA-61-CIW)

An additional strategy that EOE and WEP started several years ago and still utilizes today is to entice prospective donors providing impact data – that is, data related to the impact that the programs from their respective areas have had on their targeted populations. One document on the EOE website highlights these data for the 2012-2013 academic year.

- EOE Recruitment Initiatives touched more than 2,600 students and provided more than 160 students with the opportunity to visit UT-Austin and learn about engineering.

- EOE Academic Initiatives served more than 675 college students to help establish a strong academic foundation and promote the formation of a peer support network.
- EOE Professional Development & Leadership Initiatives served more than 700 college students to provide them with maximum exposure to engineering professionals working industry (UTA-59-CR).

In summary, the staff of EOE and WEP, seem to have had a thorough understanding of the conditions that prompted change. It is not clear in the documents whether this understanding occurred prior to the implementation of the initiatives, but there is some indication that the staff utilized the rationale to frame its current approach to the programs and services offered through EOE and WEP. Appendix E contains a summary of findings related to understanding and articulating the rationale for change, starting on page 272.

Planned attention to the environment for women and URMs.

According to an American Society for Engineering Education Annual Conference & Exposition paper, the success that the Cockrell School of Engineering has realized in the graduation rates of underrepresented student populations is largely due to the EOE FIGs.

> *Diverse: Issues in Higher Education* magazine ranked the University of Texas at Austin fourth in the nation in producing undergraduate engineering degrees for underrepresented minority groups. This success is due in large part to FIGs offered by the EOE Program. EOE FIGs serve as our most effective retention program for underrepresented minority engineering students. Since Fall 2003,

> 652 first year students enrolled in FIGs hosted by the EOE Program. Thus far, 75 percent of EOE FIG participants have either graduated from or are still enrolled in the Cockrell School of Engineering (UTA-18-CP).

The criteria that Maton (2008) described as contributing to empowering settings – a strengths-based belief system, a multi-functional role structure, a system that addresses the holistic needs of students, and highly skilled and committed program leadership – align with the mission and structure of the EOE FIGs. In a reflection on the first three years of the EOE FIGs, former director Andrea Ogilvie described the goals and objectives.

> The goals and objectives for EOE FIGs include the following: (1) develop a community of learners who feel connected with students, faculty, and staff; (2) help students make a successful transition from high school to university learning; (3) help students find a study group and get to know people; (4) increase student knowledge about engineering, strategies for academic success, and university services/resources; (5) increase the number of African American, Hispanic, and Native American students who receive degrees from the College of Engineering (UTA-17-CP).

She later went on to describe the structure of the program, in terms of the exposure that students got to various types of individuals. She explained, "EOE FIGs assist students with building a support network that includes peers, upper division students, faculty, and professional engineers." Additionally, she described the major topics that were addressed in the program, all of which centered on three main focus areas: community building, academics, and general campus information.

A staff member provided further insight into the environment that the FIGs were designed to create.

> Within the EOE program we have four FIGs, and they're major-based. One of the reasons why we do that is to get students acclimated to finding student groups, finding those peers that they're going to be studying with, finding the different strengths within what classes they may be taking…They [students] were grouped according to what they would see in similarity going through their degree plan…just so they could start to create those smaller groups and not make 1300 [number of students in the freshman class] just so daunting (UTA-07-PIT).

In addition to creating empowering settings through the first year initiatives, the EOE and WEP program staff members also believe they have realized success with underrepresented students because they prepare them for the environment in engineering. One staff member explained.

> I think through our programs we, in various ways, directly address stereotype threat and talk about the issues at hand so that when students face any of these – whether it's in school, in their classes, or in industry – they are more prepared. They are aware of what's going on and try to deal with it…I think the other thing that we do is connect them with role models who come from their same types of backgrounds or interests, look like them. And that definitely makes a difference in helping them see where they might go down the road…And again, just connecting with other students in their major with the same interests. We help speed up that progress because we help connect them a little bit earlier on than

> might have happened if they had to finagle their way through a student organization or through classes to find those students (UTA-08-PIT).

Additional findings related to planned attention the environment may be found in Appendix E on page 274.

Continuous assessment and evaluation.

As mentioned earlier, sharing the impact data with current and prospective donors is part of the strategy program staff in EOE and WEP use to raise funds. This makes assessment and evaluation a priority. A review of the documents reveals that a culture of assessment and evaluation has been in place, well before the FIG initiatives. One staff member interviewed for this study described the various types of information collected.

> We have a number of things that we are measuring. We are, of course, looking at one-year retention rates. We're looking at graduation rates. We're looking at a sense of connection to [the program area], as well as to Cockrell School. Are they feeling part of the engineering community? We're looking at if they plan to pursue additional research opportunities or if they are considering graduate school after the program…We're looking at it, and if we are not having an impact, we question why we're doing it…We've completely cut out entire programs that no longer met our needs or have passed them on to other organizations to continue because they didn't fit with our mission or vision. (UTA-08-PIT).

In addition, the programs also use the information gathered from assessment as a recruiting tool. One staff member explained.

> When students come in during orientation they have an option, a plethora of FIGs that they can choose from, and so when we're able to show them that if you don't

want to do your residential FIG but want to do a departmental FIG or you don't want to do a departmental FIG but you want to do a social group FIG, depending on what it is, we have the data to support. If you're in one of these FIGs, you do well. If you're in one of these FIGs, you do better. If you're not in a FIG, well, this is what happens (UTA-07-PIT).

For an additional summary of findings related to continuous assessment and evaluation, refer to Appendix E on page 278.

Texas public policy and UT-Austin policies.

Based on a review of the collected documents, the goals, activities, and outcomes of EOE and WEP programs have been influenced by public policy in Texas, as well as by internal policies at UT-Austin. One such public policy is the Top Ten Percent rule in Texas, which is considered an alternative to an affirmative action plan. According to a web page about the Top Ten Percent rule, "if you're in the top 10% of your high school graduating class, you're eligible for automatic admission to any public university in Texas" (UTA Document 66). To qualify, students must graduate in the top ten percent of their class at a public or private high school in Texas or other approved institution, must enroll within two years after high school graduation, and must submit an application to a Texas public institution prior to the deadline. A faculty member in the Cockrell School of Engineering explained how the Top Ten Percent rule contributed, at least in part, to the increases in the number of engineering graduates who are women and URMs.

The admissions policies to the University of Texas at Austin are such that if you graduate in the top ten percent of your high school class, you get admitted to the state university of your choice. What that does is because the state is so diverse,

> that means that our student body is diverse. There are many things that are not good about this top ten percent law, but in terms of diversity and promoting diversity and making sure that our campus is not all one ethnic group, it's wonderful. Honestly, we have a lot of people applying here that want to come here, and they're diverse. We start with a large pool (UTA-07-PIT).

These sentiments were also echoed in a state blog about the Ten Percent plan.

> Higher education leaders attribute the increased numbers and percentages of minorities, particularly Hispanics, enrolled in Texas institutions, and particularly at the University of Texas at Austin (UT), primarily to the 10 percent rule; other factors, such as increased recruitment and incentives, also have contributed (UTA-05-EOW).

Closing the Gaps is another Texas policy that, in addition to the Ten Percent rule, has likely impacted admissions in the Cockrell School of Engineering. According to the Texas Higher Education Coordinating Board (UTA-25-SGW), this plan, also referred to as the Texas Higher Education Plan, was adopted in October 2000 with strong support from the state's educational, business, and political communities. The executive summary of the plan offered this rationale for the plan:

> Texas is profiting form a diverse, vibrant and growing economy. Yet this prosperity could turn to crisis if steps are not taken quickly to ensure an educated population and workforce for the future. At present, the proportion of Texans enrolled in higher education is declining. Too few higher education programs are noted for excellence and too few higher education research efforts have reached their full potential (UTA-24-SGW).

To address these issues, the plan has four main goals, including closing the gaps in participation, closing the gaps in success, closing the gaps in excellence, and closing the gaps in research. As for closing the gaps in participation, the plan outlined goals for specific populations by 2015, with target goals set for every five years. These goals included an increase in the higher education participation rate of Black students by 56,500, an increase in the participation rate of Hispanic students by 341,600, and an increase in the participation rate of White students by 94,100 (UTA-24-SGW).
The measures identified for achieving these goals likely contributed to the large pool of students referenced earlier.

In 2006, the regents of the University of Texas system introduced the Graduation Rates Initiative to improve the graduation rates of students at UT institutions, which were below the national averages. A 2010 update to the plan described the charge to these institutions in 2006: "The Board directed the presidents of the academic institutions to align policies to raise graduation rates and to set specific graduation rate goals for both 2010 and 2015" (UTA-16-UR).

This plan led to the controversial four-year plan that the senior vice provost for enrollment and graduation management implemented at UT-Austin. An article in *UT News* explained why this program was implemented.

> For the past few years, UT has made increasing its four-year graduation rates a top priority. At 52 percent, UT has the highest public four-year graduation rate in Texas, but lags significantly behind its peer schools nationwide. UT hopes to increase its four-year graduation rates to 70 percent by 2016 (UTA-23-UNA).

Among the justifications for the four-year plan, the UT-Austin Office of Student Financial Services' infographic in the article asserted that graduating in four years would be beneficial to students because it would be cheaper for them, decrease drop-out rates, allow them to enter the workforce sooner, get them out to make room for new students, and decrease the chances for students incurring loan debt (UTA-23-UNA).

The Cockrell School of Engineering, with a four-year graduation rate of 40.9 percent for the fall 2008 cohort, was among the lowest rates at UT-Austin. According to a staff member in the School,

> [t]hat's been what has really dictated our efforts. We've always been focused on the retention piece. The goals haven't really changed; our ability to do the work has changed because the rest of the university is paying attention to this a little bit more, so we have access to better resources, better tools, in order to better track our students and see what's going on. We actually have some additional funding from the university that's come in to help us with that, so that is new (UTA-08-PIT).

Additional findings related to Texas public policy and UT-Austin policies may be found in Appendix E on page 279.

Barriers.

As mentioned earlier, a staff member interviewed for this study described the funding model for EOE and WEP as a "mixed blessing." Although the model affords both programs a great deal of autonomy with which to carry out the goals and missions of their respective program areas, it also requires a great deal of effort and some uncertainty from year to year. "Funding is always a challenge," one staff member explained. "We're externally funded. We don't have funding from the university for any staff or for our programs, so that's a continual challenge to raise the funds that we need to do the work that we do" (UTA-08-PIT).

Another staff member made note of how that has sometimes impacted aspects of their programs and services.

> We started out by paying graduate students a small stipend [for their work with FIGs]. We don't do that anymore; it's strictly volunteer. We had funding at the beginning to be able to do that, and when that funding went away, we just recruited students on a volunteer basis (UTA-08-PIT).

According to a news article in the Daily Texan Online (UT Document 63), at the start of the FIG program, mentors were paid $10 per hour for up to 19 hours per week. Later that changed to $500 for one semester. One might expect a decline in volunteers as a result of eliminating this particular incentive. However, according to one staff member they "have never had a drop in participation" (UT-08-PIT).

The two programs have had to be resourceful and creative through the years in response to their unique funding models. One staff member described this resourcefulness.

> We've had to be more creative in how we reach students. One of the biggest misconceptions is that we have to reach them all their first year. Well, that doesn't necessarily have to be the case anymore. Now that we have a four-year plan, we can look at reaching…a group of students their first year, a cohort of students their second year, and that way by the four years that they come through, we have made some sort of connection with them…We've learned how to best

utilize these resources – where we may need supplies, where we may not need supplies…It's just management. It's resource management. That helps us in determining what the true focus is (UTA-07-PIT).

Another staff member echoed this necessary attention to resourcefulness. "I would say the reason we have been able to be successful is because we're very resourceful," that staff member explained. "We run our programs on nothing. We buy food, but for everything else, we're getting things donated" (UTA-08-PIT).

In addition to the challenges of fundraising, the funding model also is the source of another barrier. "I think there are a lot of positives in the way that we are left alone [because of the funding model]," this staff member reflected. "At times, we are forgotten because we are off on our own." The same staff member went on to explain.

> One of our biggest challenges as of late has been ensuring that the departments and the faculty in those departments and the department chairs know what we're doing and know that we are an expert in this space so they can partner with us on efforts…We have some expertise in those spaces and can help them…One example in particular: In the [a particular] department, some of the faculty were going to other universities asking what they were doing to recruit the populations of students we serve, trying to find different ways to do it. Many of the schools that they went to have copied programs that we do. We have those best practices. We are the leader in that space. They didn't really get it until we flat out said it. It's one of those cases where you're recognized more outside your organization than you are inside your organization (UTA-08-PIT).

A summary of findings about the barriers faced at UT-Austin may be found in Appendix E on page 280.

Each of the strategies that was highlighted in the documents helped to provide insight into what has made the programs at UT-Austin successful and sustainable. The barriers addressed in the documents were also helpful in determining what the barriers were and how the faculty and staff associated with the initiatives in CSE overcame those obstacles. A complete summary of findings is available in Appendix E, starting at page 272.

CHAPTER 7
Cross-Case Analysis

An important aspect of this study was cross-case analysis, as the findings from comparing several cases are more robust than those from a single-case analysis (Herriot & Firestone, 1983), and comparisons across cases help determine what generalizations, if any, exist. Several common strategies for increasing the enrollment and graduation rates of women and underrepresented minorities (URMs) surfaced across each of the cases, in spite of the fact that the two departments and one school vary in size, discipline, and culture. Other strategies – those related and unrelated to the Transformational Change Model for Inclusive Excellence (TCMIE) model – were specific to each institution.

Common Strategies

In terms of the TCMIE, these similarities were most pronounced with regard to articulation of the rationale for change, assessment and evaluation, professional development for students associated with initiatives and planned attention to the environment for women and URMs. Beyond the model, similarities surfaced in the roles that campus culture, selective admissions, external funding, and leadership motivation and interest played in advancing the initiatives in each department and school. Additional strategies unrelated to the TCMIE were only shared by two – Harvey Mudd College (HMC) and the Massachusetts Institute of Technology (MIT) – such as the inclusion of introductory computer science courses in common core requirements and an emphasis on better instruction for all learners. The only common barriers that surfaced in the study were related to stereotypes about diversity and excellence and challenges with recruiting African American students.

Understanding and articulation of the rationale for change.

Understanding and articulating the rationale for change seemed to be the starting point from which each of the initiatives was launched. There was evidence in numerous documents that each of the departments and school conducted thorough research on general trends and on the specific trends or issues within their respective departments and school prior to developing the initiatives and during later phases of implementation.

As an example, at HMC sixteen documents referenced the research that several computer science faculty members had done to understand why girls/women were not attracted to computer science, and 3 documents referenced the research that these same faculty had done on enrollment trends within the computer science department – both in understanding what the enrollment trends were and the reasons behind the enrollment trends. Similarly, one document at MIT referenced the trends in physics enrollment at Harvard as the impetus for the flexible major option, and eight documents referenced the research that Dr. Belcher, champion of the Technology Enabled Active Learning (TEAL) initiative, had done on student engagement teaching models in physics, including the SCALE-Up model attributed to Professor Beichner at North Carolina State University. Likewise, one document at the University of Texas at Austin (UT-Austin) referenced the research conducted by faculty and students on various faculty-student research models at the University of California Davis and other institutions prior to implementing the Graduates Linked with Undergraduates in Engineering (GLUE) research program for women enrolled in the Cockrell School of Engineering. In addition, two documents referenced the research that had been conducted on First-year Interest Group (FIG) models at other research institutions prior to implementing the Women in Engineering Program (WEP) and Equal Opportunity in Engineering (EOE) FIGs.

Although each department and school had a similar focus on research, each differed in how the research was utilized to advance initiatives. At HMC, for instance, the referenced documents indicated that understanding and articulating the rationale was key in helping faculty members in the department of computer science determine how best to address the reasons they found that girls and women were not attracted to the discipline of computer science. Documents also showed that articulating the rationale became part of the department's recruiting efforts. At MIT, collected documents revealed that articulation of the rationale was utilized more as a means of justifying the initiatives to secure buy-in and advocacy from senior administrators in the department of physics, who ultimately made the final decisions as to whether to implement flexible major options and the TEAL format for introductory physics courses. In contrast, because of the unique way in which both EOE and WEP are funded at the Cockrell School of Engineering at UT-Austin, documents seemed to show that articulating the rationale for program initiatives was primarily targeted to prospective corporate and private donors, although also used for student recruitment for the various offered initiatives. Additional cross-case findings related to understanding and articulation of the rationale for change may be found in Appendix F on page 281.

Assessment and evaluation.

Likewise differing in how they were utilized in each department and school, assessment and evaluation were also important strategies for advancing initiatives. At HMC, the comprehensive approach to assessing and evaluating the three major initiatives – the introductory computer science (CS) course, the annual trip to the Grace Hopper Celebration (GHC), and research opportunities – were instrumental in helping faculty "tweak" each initiative to better meet the needs of students, as noted in ten documents. The faculty in the department conducted assessment during various phases of implementation (e.g., at the beginning and end of the introductory course, before and after the GHC, before and after research experiences) and made changes based on those assessments (e.g., incorporating Picobot so that students with weaker programming backgrounds could learn to program, helping students with scheduling courses to avoid conflicts with GHC, and adding mentors to assist students who were new to research). Ten different documents also revealed that results, most of which highlighted the benefits of the three initiatives, were utilized in recruiting students and donors and as a justification for collaborating on similar initiatives at other institutions.

At MIT, thirteen documents discussed the comprehensive assessment and evaluation of the TEAL initiative by a visiting professor Dr. Dori, who was brought in specifically for her expertise in assessment. Two documents mentioned tracking participation in the flexible major, and one document described the various types of information collected by staff members with regard to Office of Minority Education (OME) academic initiatives such as Seminar XL. The results of the assessment and evaluation seemed to serve as a tool for maintaining support from senior leaders in the physics department, particularly as it relates to the TEAL format for teaching introductory courses, which was initially a highly debated approach among faculty and unpopular among students. Twelve documents noted that the assessment and evaluation results were also referenced when revising various aspects of both the flexible major option and the TEAL format for teaching introductory physics courses (e.g. training students how to do group work, training faculty on technology, etc.).

Sixteen documents from UT-Austin discussed the comprehensive assessment of EOE and WEP first-year-interest-group initiatives by program staff, and four documents referenced the changes that have been made based on the results of this assessment and evaluation (e.g. moving from one semester to two semesters of FIG, changing emphasis of FIG from social to academic, etc). The staff of EOE and WEP seem to primarily use assessment results, the majority of which show benefits to students from participating in FIGs, to recruit students for participation in the FIGs and to encourage financial support of the initiatives from private and corporate partners. Refer to Appendix F for a summary of cross-case findings related to assessment and evaluation, starting at page 284.

Planned attention to the environment for women and URMs.

Each of the departments and school focused attention on the role that students played in learning, with particular emphasis on how more experienced/skilled students could assist with group learning. At HMC, for instance, two documents referenced how introductory course task groups were developed to include experienced and inexperienced student programmers. Similarly, three documents from MIT described how TEAL classroom groups were developed to include students with strong and weak backgrounds in physics. Likewise, five UT-Austin documents referenced the interaction between FIG student mentors and students in the FIG courses.

There was also an emphasis on fostering a sense of community among program/initiative participants at each of the institutions. For instance, one document from HMC referenced the community that was formed among Grace Hopper Conference participants. At MIT, one document described a faculty member's perception that the TEAL format, in addition to helping students master complex physics concepts, also helped to foster community. Similarly, two staff members at UT-Austin discussed EOE and WEP program goals of fostering community through the various programs and initiatives that both programming areas sponsor.

In addition, each department and school focused attention on psychological issues that students faced as a result of being members of underrepresented groups on campus. Five documents at HMC referenced the attention placed on helping female students manage imposter syndrome and encouraging them that they can persist in challenging courses, even when the rigor of the work makes them feel like they do not belong. Two documents at MIT revealed that the Office of Minority Education focused on assisting students with managing imposter syndrome and stereotype threat. Similarly, two documents from UT-Austin revealed an emphasis on helping students cope with feelings of isolation in courses and activities in which there was not a critical mass of URMs. Although this emphasis was likely offered in other areas of the institution (e.g., Office of Institutional Diversity at HMC and the Division of Diversity and Community Engagement at UT-Austin), it probably helped to have an additional emphasis on psychological development in students' academic departments and school. See Appendix

F on page 283 for a summary of findings related to planned attention to the environment for women and URMs.

Campus Culture.

Analysis of numerous documents from each institution revealed that the environments in the departments and school, as well as in the larger campus communities were conducive to the fostering of diversity initiatives. HMC, according to seven documents, has a reputation for placing an emphasis on innovative pedagogy and for developing structures and hiring practices that encourage diversity among students, faculty, and staff. Similarly nearly thirty documents at MIT make reference to the fact that members of the campus community are accustomed to grappling with tensions around issues of inclusion and excellence in ways that are more open and transparent than at many other institutions. In addition, there are structures in place to support hiring of diverse faculty and staff, mentoring of new staff, and the recruitment of diverse students. In much the same way, seven documents from UT-Austin specifically reference campus initiatives related to increasing diversity at UT-Austin, such as the comprehensive offerings through the Division of Diversity and Community Engagement. A summary of cross-case findings related to campus culture may be found in Appendix F on page 284.

Admissions policies.

Each of the institutions' admissions policies played a role in the success of enrolling and graduating women and/or URMs by providing a diverse pool of highly talented students from which to recruit students into the various majors. At HMC, two documents described the role that the admissions staff played in attracting a diverse group of students to the College and the fact that these students are high-achieving students who have strong academic backgrounds, even if their exposure to computer science may be limited. At MIT nearly twenty documents mentioned the priority that the admissions staff place on enrolling diverse classes of students each year and that like HMC, these students are high-achieving students who have strong academic backgrounds. As mentioned previously, there are several admissions policies at UT-Austin that are dictated by the state of Texas and the UT-Austin system and acted upon by the admissions staff. These policies, described in fourteen documents, allow for increased enrollment of women and URMs and ensure that these students are in the top seven to ten percent of their respective high school classes, even though there was some speculation about how the top ten percent at certain institutions compare across high schools. More findings related to admissions at UT-Austin may be found in Appendix F on page 285.

External funding.

Funding, which, as noted earlier, is related to buy-in and advocacy, is considered here as a separate strategy because not all of the funding is related to resources that senior leaders provide. In fact, much of the funding that each of the departments and school received was from external sources in addition to internal sources. As an example, eighteen documents from HMC detailed how National Science Foundation (NSF) grant funding, corporate and private donations, and allocations from the president's office contributed to the three major initiatives undertaken in the department of computer science. At MIT, twelve documents referenced the role that two major donations from a corporation and a private citizen, totaling $35 million, played in implementing the TEAL initiative. Likewise, external funding is critical to the work of EOE and WEP at UT-

Austin, as sixteen documents emphasized that both program areas rely primarily on external contributions. A summary of findings related to external funding may be found in Appendix F on page 285.

Leadership motivation, interest, and skill.

Numerous documents indicated that leaders associated with the initiatives at each institution were skilled in their disciplines and passionate about efforts with which they were involved, as evidenced by the time and effort they put into implementing the initiatives. At Harvey Mudd College, for instance, five news articles and the transcripts from the two interviews referenced the motivation of leaders, such as Dr. Maria Klawe, Dr. Christine Alvarado, and Dr. Libeskind-Hadas, who were associated with the revamped introductory course, Grace Hopper participation, and research opportunities for freshmen students. Six documents indicated that these leaders were highly skilled and competent in computer science and in project/initiative planning and development.

Similarly at MIT, six documents provided examples of how leaders associated with initiatives were highly motivated around diversity issues, with specific emphasis on the personal experiences that influenced their interest in diversity issues. One document focused on the time that went into researching and planning for the TEAL initiative. Seven documents also focused on the expertise of the faculty, administration, and staff associated with the initiatives, many of whom had won awards in their fields for scholarship and research. Refer to Appendix F on page 285 for a summary of findings related to leadership motivation and skill.

Strategies common to HMC and MIT.

Some strategies were common only to HMC and MIT. One of these strategies was specifically related to the new introductory computer science course at HMC and the new physics introductory courses taught in the TEAL format at MIT, both of which were high impact visible actions that were designed to positively influence learning outcomes by using technology to support student engagement, such as solving computer- and physics-related problems in peer work/study groups. What made these courses at both institutions high impact was the fact that the courses were both among the common core requirements at each institution, which meant that every student enrolled at the institution had to take one of the introductory courses. The documents collected at both institutions suggested that computer science and physics are not typically a part of the common core requirements at most institutions. The fact that these two introductory courses were part of the core requirements potentially contributed to the success of the initiatives because these courses exposed all first-year students to the disciplines of computer science and physics. Seven documents at HMC described how the introductory CS courses fit into the common core requirements, and five documents at MIT described how the introductory physics courses in the TEAL format fit into the General Institute Requirements (GIR).

Relatedly, a circumstance that was common to both HMC and MIT was that the overarching goals of the introductory courses that were initiated were not focused specifically on underrepresented student populations (or at least not initially at HMC). Instead, the champions of both initiatives were focused primarily on improving learning outcomes for all students. In the case of HMC, two documents suggested that the dramatic increase in the number of CS majors after the new course was introduced redirected the focus of the initiative toward recruiting more women into the program. Similarly, at MIT, the TEAL format was not designed as a measure to attract women and URMs; rather, one document indicated it was designed primarily to increase learning outcomes. A summary of these findings is in Appendix F on page 285.

Common Barriers

HMC and MIT seemed to have wrestled at some point with the belief among members of the campus community that increasing diversity in the computer science department would necessitate the lowering of standards and academic rigor. One document from HMC referred to how this culture of skepticism is being slowly replaced by a more welcoming culture of diversity and one in which students and faculty across campus do not have limited views of who can be successful in computer science. Similarly, at MIT one document discussed implicit and explicit bias against women and URM faculty based on the perception that they were not as capable. As in the case with HMC, this document also discussed the progress that has been made with eliminating that perception and becoming a more welcoming environment for these underrepresented populations.

Another barrier common to HMC and UT-Austin was the challenge of recruiting African American students. In one document at HMC, an administrator described the challenge of recruiting URMs into the discipline of computer science, noting that there had been some progress made in recent years with recruiting Hispanic students, largely because of the larger population of Hispanic students in California. However, according to this administrator, similar growth had not been seen with recruiting African American students, although the administrator noted that there were promising signs of progress. Likewise, a document from UT-Austin referenced some of the challenges associated with recruiting African Americans into the discipline of engineering over the years, noting that even though progress has been made, it has not been comparable to progress made with recruiting Hispanic students. Refer to Appendix F on page 285 for a summary of findings related to common barriers.

Notable Differences Across Institutions

With regard to the TCMIE, there were several notable differences around buy-in and advocacy, collaborative leadership at multiple levels, professional development for faculty associated with initiatives, and the sequencing of strategies. Beyond the model, there were other differences related to the impetus for change in each case and the leadership associated with each initiative. There were also differences in the types of barriers that each institution faced.

Buy-in and advocacy of senior leadership.

In each of the cases, buy-in came from different levels of senior leadership both internal and external to the departments/schools. At HMC, the president, Dr. Maria Klawe, served as an advocate for the three initiatives at HMC. Twenty documents described the roles she played as advocate, including providing funding for initiatives, making participation in the initiatives rewarding for the faculty involved, and actually participating in recruiting efforts for the computer science department.

At MIT, ten documents described the role that senior leaders of the department played in supporting the initiatives in the department. Champions of the earlier initiatives secured buy-in from the head and associate head of the department, Dr. Kastner and Dr.

Greytak, respectively, who supported both the flexible major option and the TEAL initiative, even when the latter was not popular among students and faculty. In subsequent years, Dr. Bertschinger served as a major advocate for creating a welcoming environment within the department for female and URM students and faculty by actively seeking to understand the issues these students and faculty faced, working cooperatively with the Office of Minority Education to address issues, inviting external groups to conduct assessments of the department with regard to diversity and inclusion, and by working to develop supportive policies within the department.

Although faculty and administrators were generally supportive of the efforts of EOE and WEP at UT-Austin to focus on the retention and graduation rates of women and URMs, the program administrators in EOE and WEP were, for the most part, given the autonomy to develop whatever initiatives they deemed most appropriate for achieving their goals and those set by policy in Texas. This autonomy was directly related to the fact that both programming areas were almost entirely externally funded. As a result, the administrators in EOE and WEP were primarily focused on securing buy-in from current and prospective corporate and private partners. See appendix F on page 281 for summary findings related to buy-in and advocacy of senior leadership.

Collaborative leadership at multiple levels.

In each of the cases, there was collaborative leadership at multiple levels, particularly with regard to the larger initiatives, however, the nature of this leadership differed between cases and within cases, depending on the initiative. At HMC, for example, the changes to the introductory course involved grassroots leadership at the faculty level. The organizing member of this group, according to documents, was Dr.

Libeskind-Hadas, a tenured faculty member who would later become chair of the department. Prior to the hiring of Dr. Christine Alvarado, this group of faculty was all-male. Even though members of this group would later get buy-in from the president, they initiated changes without consulting with external parties, as indicated in transcripts from interviews from an administrator and faculty member in the department. The other two initiatives – the GHC conference participation and the research opportunities for rising sophomores – were led by individual faculty members in consultation with other faculty members and staff from various departments and offices at the college.

At MIT, the flexible major option seemed to have been initiated by a similar working group among faculty in the physics department that was led by one of the department heads. The TEAL format for teaching introductory courses, on the other hand, was initiated by a faculty member who enlisted the support of other tenured and non-tenured faculty members. This working group operated at the periphery of the department until the initiative was ready for piloting. The other initiatives within the department, such as the invited review of Title IX policies within the department seemed to be top-down initiatives led by department head, Dr. Bertschinger.

According to six documents, the EOE- and WEP-sponsored FIGs at UT-Austin were organized by EOE and WEP staff members in collaboration with faculty, students, and advisors. According to those interviewed for the study, faculty played more of an active role in developing WEP programs. As an example, the GLUE research program for women in engineering was initiated by a faculty member in consultation with staff members in WEP, and faculty have since remained actively involved with that initiative. In addition to collaborations with various members of the University community, in the

State of the Cockrell School address in 2008, there was a specific reference to collaborations with industry professionals, 500 of whom volunteered with EOE and WEP initiatives. A summary of findings related to collaborative leadership may be found in Appendix F on page 282.

Professional development related to proposed changes.

Although documents indicated that there was professional development related to the new initiatives at each of the institutions, each case differed in the type of professional development in which those associated with the initiatives were engaged. For instance, at HMC, one document indicated that there were no separate workshops or training sessions. Instead, the interview transcript from the faculty member interviewed for the study revealed that the work that faculty put into researching trends and innovative practices served as professional development for all those involved. There were, however, training sessions and workshops for faculty at other institutions who were implementing introductory courses at their institutions based on the course at HMC, as documented in two documents.

At MIT, five documents indicated that there were training sessions designed specifically to prepare faculty for utilizing the lesson plans and technology associated with teaching in the TEAL format. There were also training sessions designed to prepare faculty for teaching seminars associated with the FIGs in the Cockrell School of Engineering at UT-Austin, as indicated in one document. These training sessions were offered through the larger FIG program at UT-Austin and were not required. A summary of findings related to professional development is in Appendix F on page 283.

Sequencing of strategies.

Although the initiatives in each case seemed to all stem from understanding and articulating the rationale for change, the sequencing of strategies beyond that strategy was different across and within cases. Consistent with the transformational change model by Kezar and Eckel, the sequencing of strategies at each institution was not linear in nature. Instead, strategies were clumped together and revisited at different times throughout implementation.

Sequencing of strategies in the department of computer science at HMC.

The sequencing of strategies at HMC was referenced in twenty-seven documents. Faculty in the department had begun work on the introductory course at least a year before they piloted the course in 2006. During the planning stages, faculty engaged in several strategies, including assessment and evaluation of the introductory course that was offered prior to implementation, research of trends and innovative instruction methods, collaborative leadership, professional development, and planned attention to the environment. Together, these led to the articulation of the rationale for change. Early in the implementation phases of the introductory course, the faculty secured buy-in from the president and began assessing and evaluating the new introductory course, making revisions to the course (flexible vision) as deemed necessary.

Concurrent with those activities, Dr. Christine Alvarado sought buy-in from the president with regard to securing funding to take freshman females to the Grace Hopper Celebration. This was then followed by collaborative efforts with various parties internal and external to the computer science department with regard to the logistics involved with taking the students to the conference and then assessment and evaluation of the conference experience. Changes to the conference attendance were then made as needed in response to the assessment and evaluation (flexible vision). These steps were repeated each year of implementation and are now standard strategies to sustain the program.

Similarly, Dr. Ran Libeskind-Hadas during the same year sought buy-in from the president for the research opportunities for rising sophomore females and then worked with Dr. Klawe to secure funds. This was followed by collaborative efforts among faculty in the department and at other institutions to provide research opportunities for students and then assessment and evaluation of students' research experiences. As with the other initiatives, changes to the research efforts were made based on assessment and evaluation, and this process has been repeated each year.

Sequencing of strategies in the department of physics at MIT.

The sequencing of strategies at MIT was referenced in twenty-five documents. The first initiative implemented was the flexible major option in 2000. Prior to implementation and under the leadership of Dr. Greytak, who was associate department head at that time, the main strategies utilized appeared to be assessment of the number of majors in the department which led to the articulation of the rationale for change. These two led to collaborative efforts among faculty in the department to plan for offering the flexible major option, including planned attention to the environment. After implementation, there was continuous assessment and evaluation and collaborative leadership, which seems to have been continuous throughout implementation and since.

At about the same time that the flexible major option was implemented, Dr. Belcher, a full professor in the department of physics, was gearing up for the TEAL format for teaching introductory physics courses. Prior to implementation, the strategies that Dr. Belcher employed seemed to be assessment and evaluation of the introductory course that was in place prior to the new initiative, research on the trends and innovations in physics instruction, articulation of the rationale for change, and collaborative leadership to develop the curriculum for the introductory physics class with planned attention to the environment. Dr. Belcher also secured funding by applying for the funds from the Microsoft Corporation and d'Arbeloff and buy-in from the senior and associate department heads. During the time that the format was piloted and during the first phases of full implementation, Dr. Belcher and faculty associated with the initiative seemed to continue working collaboratively to further develop the curriculum. The courses were revised as needed (flexible vision), and it was determined that faculty needed training on how to utilize technology in the classroom effectively (professional development). Because the course was not popular among faculty and students at first, securing buy-in was a revisited a couple of times during the implementation of the program. Collaborative leadership, continuous assessment and evaluation, planned attention to the environment, and revisions to the TEAL format based on assessment and evaluation continued throughout the implementation of the TEAL format, and each of these strategies has been conducted each year since.

***Sequencing of strategies at the Cockrell School of Engineering at UT-Austin*.**

The strategies utilized in the Cockrell School of Engineering at UT-Austin prior to implementation of the WEP First-year Interest Groups (FIGs), included collaborative leadership at multiple levels. In 1998, the staff in WEP worked with the staff of the larger FIG initiative at the University to include the WEP FIGs as part of the piloting of the FIG program. This included having the faculty, staff, and students associated with the WEP FIGs participate in training sessions offered through the larger FIG initiative. There was also attention to the rationale for the WEP FIGs, as described in documents about its implementation, as well as planned attention to the environment, in particular developing the curriculum for the seminar class to help female majors learn what to expect from and how to manage the demands of the engineering major.

Assessment and evaluation of the WEP FIGs were conducted after the pilot, and the program was revised based on the results of the evaluation. After the pilot was complete and the initiative moved into full implementation, collaborative leadership continued, in terms of developing the FIGs to meet the desired objectives. Planned attention to the environment, continuous assessment and evaluation, and making revisions to the FIGs based on the results of the assessment and evaluation were other strategies utilized throughout implementation and since. These same strategies were utilized in 2003, when the EOE FIGs were implemented. Similar sequencing of strategies occurred with other initiatives in CSE. The only difference was that the other initiatives were not part of a larger University initiative.

Differences in Barriers across Cases

The barriers at each of the institutions were largely contextual. The administrator and faculty member interviewed for this study indicated that the barriers encountered at HMC were minor and included residual stereotypes and perceptions that standards were lowered to accommodate female CS majors, as well as scheduling issues associated with participation in the Grace Hopper Celebration of Women in Computing. A summary of these findings is in Appendix F on page 285.

At MIT, the barriers associated with the implementation of the TEAL initiative, as described in six documents, included a backlash from students who preferred the lecture-based format for introductory physics courses and resented the attendance policy for the new course format. In addition, initially not all faculty were convinced that the TEAL format was more effective than the lecture-based format, as was described in twelve documents. Other barriers were related to finding a location for the TEAL classrooms and a perception among some faculty that focusing on inclusion lessens the rigor and quality of instruction. Summary findings related to barriers at MIT are in Appendix F on page 285.

Although considered a "mixed blessing," the staff from UT-Austin who were interviewed for this study indicated that the securing external funding for staffing and programming was challenging. An additional challenge was making sure faculty were aware of all the services and programs provided through EOE and WEP. Additionally, there was discussion in one document about the difficulty of enrolling African Americans at rates comparable to Hispanic students. A summary of findings related to barriers at UT-Austin is available in Appendix F on page 285.

Cross-case analysis allowed for a better understanding of the strategies that were were common across all cases, as well as those that were dependent upon context. This analysis paved the way for reflection on the implications from the study findings and recommendations for future research. A complete summary of findings related to cross-case analysis may be found in Appendix F, starting on page 281.

CHAPTER 8
Conclusion

As is commonly noted in the literature, qualitative studies are not designed to provide statistical generalizations. It would not be feasible, therefore, to generalize strategies utilized in the department of computer science at Harvey Mudd College (HMC), the department of physics at the Massachusetts Institute of Technology (MIT), and the Cockrell School of Engineering at the University of Texas at Austin (UT-Austin) to other college and university contexts. There were too many factors involved that were specific to the individual context, such as the fact that these institutions are highly selective, highly resourced, and highly recognized for innovative practices. In addition, there are differences in the size, common core and curricular offerings, departmental structures across the campus community, and missions at each of the institutions.

Although qualitative studies are not designed to make statistical generalizations, studies such as this one are designed to make analytical generalizations or to provide insight into the type of analysis or processes used to arrive at a particular approach or outcome and to glean from that information strategies that can be adapted and used with the hope that it might provide similar results in other settings (Yin, 2003). As such, findings from the cases in this study provide useful information with pertinent implications. In addition, the findings also raise questions that suggest future research

Unexpected Findings and Observations

Several findings in this study were surprising. As an example, it is often assumed that buy-in from senior leadership is necessary to ensure that programs achieve systemic or transformative results. At UT-Austin, however, the external funding model was a departure from this assumption. Because the Equal Opportunity in Engineering (EOE) program and the Women in Engineering Program (WEP) were externally funded, they were not impacted by funding priorities established by administrators in the Cockrell School of Engineering and in the University at-large or by state or federal budget cuts, which have been common occurrences in recent years. Additionally, because staff members were able to secure external funding from industry partners who had interests in diversity and inclusion within their organizations, EOE and WEP fundraising efforts were not competing with other fundraising efforts within the Cockrell School of Engineering or within the larger University. As a result, staff had autonomy to determine which initiatives to pursue, as long as they secured funding to support them. Similar programming areas at colleges and universities rely on the institution to fund their efforts, even though initiatives for women and URMs are not always a top priority among other competing initiatives. As a result, many program staff members attempt to achieve the goals of retaining and graduating women and/or URMs with limited funding, which can limit the impact of the initiatives. The implication is that staff in these programming areas may benefit from securing external funds from discipline-related organizations that have a vested interest in diversity and inclusion efforts, which could increase autonomy in determining the priorities that are most effective and increase the budget for these initiatives.

Another surprising finding relates to faculty buy-in for changing the introductory computer science course at HMC. It is often assumed that faculty members are protective of their courses and resistant to embracing innovative methods of instruction. At HMC, however, there did not seem to be resistance to changing the course. Instead, most of the faculty seemed interested in improving the introductory course and over half participated in efforts to develop the new curriculum for the introductory courses.

An additional surprise was that the physics faculty and administrators at MIT, even though they have conducted extensive assessment of individual initiatives, have not engaged in a comprehensive effort to understand which of their initiatives have most influenced the decisions of women and URMs to major in physics. Given the success they have had, such an undertaking would likely provide insight that would be beneficial not only to the department, but also to other institutions.

Implications

Findings from these cases provide useful information relevant to strategies for approaching transformational change, change management competencies, pedagogy/ academic policies, and general practice that may inform the efforts of faculty, staff, and administrators, within and beyond the STEM disciplines, who are concerned with increasing enrollment and graduation rates of underrepresented students.

Implications related to transformational change strategies.

The findings in this study revealed that each of the departments and school utilized all of the strategies in the TCMIE framework to some degree. The findings confirmed some existing assumptions, but also challenged other assumptions.

Understanding and articulating the rationale for change.

Articulating a clear and concise rationale seemed to impact buy-in of senior leaders at HMC and MIT and also seemed to be important for attracting corporate sponsors at UT-Austin. In each case, faculty and staff not only identified trends at other institutions, but they were also able to capture the trends within their departments/schools and to convey why it was important to focus efforts on retaining and graduating more women and/or URMs. Based on these observations, it seems important that those associated with efforts to broaden the participation of women and/or minorities should focus not only on researching relevant trends related to the changes they seek to make, but also on situating their research within the goals of the department/school and within the context of the industries that have an interest in the prospective employee pool.

Buy-in from senior leadership.

Although the UT-Austin case illustrated that buy-in from senior leadership is not always necessary to achieve results, buy-in from the president at HMC and from physics department heads at MIT showed that buy-in from senior leadership can advance efforts. At HMC, for instance, Dr. Klawe, who was well-known for her advocacy for women in the STEM disciplines even before she became president at HMC, used her platform to bring national attention to the efforts of the computer science department. Additionally, she rewarded the computer science faculty for their efforts, and she participated in numerous activities within the department. These actions served not only to provide momentum for the computer science faculty's efforts, but national exposure and active participation in the department's efforts also served as a recruiting strategy. Along with considering ways in which faculty, staff, and administrators who endeavor to broaden participation in their respective areas, can secure buy-in from senior leadership, these professionals should also consider specific ways that senior leadership can contribute to the goals of the initiative.

Collaborative leadership at multiple levels.

Collaborative leadership at multiple levels was a strategy utilized in each model department/school, although the type of collaborations differed between institutions and within department/school depending on the context. The implication is that when planning for high-impact initiatives, those that reach a large percentage of the targeted population, attention should be directed to discerning the types of collaborative efforts that make the most sense given the context. In some contexts, for instance, it might be necessary to have a highly organized planning group of individuals from various departments. In other settings, it might only be necessary to consult on occasion with individuals who have some interest in the goals of the department/school.

Flexible vision.

Flexible vision seemed most important with regard to addressing barriers and reacting to assessment and evaluation of initiatives. As an example, at HMC faculty had to be flexible in their vision to have freshmen attend the Grace Hopper Celebration each year, as it turned out that doing so interfered with important activities in other core courses. At MIT, the physics faculty learned to be more flexible with regard to meeting the needs of students who were interested in physics but also interested in using what they learned in physics in practical applications in which they had interest. Similarly, UT-Austin determined through assessment and evaluation that it was important to include an academic focus in the FIG seminar, in addition to a focus on the social aspect of students' experiences as engineering majors. It follows, then, that it may be beneficial throughout the implementation process to focus attention on the barriers that arise and on the results of assessment and evaluation to determine if the vision needs to be amended.

Professional development related to proposed changes.

The type of professional development differed between and within the model departments/school, depending on the initiative. The implication is that professional development does not always entail workshops and training sessions. In some situations, such as at HMC, participating in committees tasked with identifying innovations in instruction or other practices can serve as professional development.

Planned attention to the environment for women and URMs.

The success of the departments/school seemed to be related to understanding the needs of the diverse groups of students and fostering an environment that took these needs into consideration and promoted confidence in students' ability to succeed. At HMC, for instance, priority was placed on understanding how intimidation weighed into female students' choice of majors. At MIT, priority was placed on providing flexibility to students who had an interest in physics but had career interests outside of physics. Likewise, staff members in EOE and WEP were responsive to students who did not know what to expect from engineering. This approach likely contributed to the success each department/school achieved with regard to increasing the number of women and URM graduates and should be considered by those championing similar initiatives.

High-impact visible actions staged over time.

Two aspects of the findings related to visible action and staging have implications for faculty, staff, and administrators interested in systemic efforts to broaden the participation of women and URMs. In each case, pilot studies were conducted before going mainstream, which enabled faculty and staff to revise the initiatives as necessary or provide additional training where needed. Another finding at HMC and MIT showed that with careful attention to strategy, grassroots efforts, such as those by faculty at HMC and MIT, can be successful and lead to systemic change.

***Continuous assessment and evaluation*.**

Continuous assessment and evaluation was a strategy that seemed to impact all other strategies in some way. The implication is that assessment and evaluation should be factored into every initiative from the start, as doing so has the potential to impact buy-in from senior leadership and/or prospective donors, articulation of the rationale, collaborative leadership, flexible vision, professional development, planned attention to the environment, and visible actions that address the rationale.

***External funding*.**

In addition to the strategies from the Transformational Change Model for Inclusive Excellence, external funding was a strategy utilized in each department to develop initiatives. This suggests the importance of securing external funds, in addition to departmental and/or institutional funds when pursuing initiatives designed to increase the retention and graduation rates of women and URMs.

***Utilizing the Transformational Change Model of Inclusive Excellence*.**

As noted earlier, Dancy and Henderson (2008) highlighted the inability of leaders to choose appropriate change models prior to engaging in new initiatives in STEM disciplines. The findings in this study revealed that each of the departments and school utilized all of the strategies in the TCMIE framework to some degree, which makes the model a useful way to organize and prepare for implementing diversity initiatives such as the ones in this study. The model may be especially useful for program managers who may have expertise related to the actual program being implemented but limited knowledge about how to secure buy-in and momentum for the initiative.

The framework presents the ideal set of circumstances that would likely contribute to successful initiatives; however, it may also be helpful to look at how individual strategies from the framework might make up for areas that are lacking. As an example, the UT-Austin case revealed the level of autonomy that EOE and WEP programs had in developing initiatives because they are externally funded. In departments or schools where it has been difficult to get senior level buy-in, in terms of providing adequate resources, a particularly useful strategy might be to identify companies whose mission and goals are aligned with a particular campus diversity effort or to identify grant opportunities offered by related government agencies.

Using existing program models.

Beyond the TCMIE model, an interesting implication is that all initiatives do not have to be developed "from scratch"; rather, leaders can adapt existing campus models to meet their needs. For instance, at HMC, there was already a research initiative in place within the computer science department, so the faculty adapted that model to address the specific goal of recruiting first-year female students into the computer science major. Similarly, the EOE and WEP FIGs were incorporated into the campus program for FIGs and adapted to fit the unique needs of Cockrell School of Engineering students.

Change management competencies.

Just as it is important for those who are leading initiatives to be competent in the disciplines related to the initiative, the findings from this study suggest that it is also important for those leading initiatives to be competent in managing change. It is not enough to know what to do, it is equally important to know strategies for how to advance the initiatives. Thoughtful consideration of these competencies can be especially useful with regard to assembling a team of individuals to work on departmental/school initiatives or when developing position descriptions for hiring purposes.

Program management competencies.

Including team members who have program management skills, such as being detail-oriented, competent in managing budgets, competent in delegating tasks and setting deadlines, is likely beneficial. Such was the case with the champions of initiatives at each institution, who organized research teams, administered NSF grants, developed engaging curricula, made arrangements for travel to conferences, scheduled faculty to teach courses, and other similar tasks.

Access to influential networks.

In each case, champions of some of the major initiatives had access to networks that proved beneficial in helping to advance these initiatives. At HMC, for instance, the president and faculty in the department of computer science had access to industry leaders in computer science who contributed to initiatives such as the Grace Hopper Celebration of Women in Computing initiative and who were instrumental in raising the national profile of the institution. At MIT, Dr. Belcher had access to faculty who had done research in engaged learning at other institutions, such as the SCALE-Up model at

North Carolina State University, from which the TEAL format for teaching introductory physics courses was adapted. At UT-Austin, the directors of EOE and WEP were engineering graduates who had worked in engineering fields prior to joining the staff at UT-Austin. As a result, they were connected to the industry networks from which they solicited funding partnerships. This suggests the importance of determining which members on the team have access to influential networks and the ways in which these connections might benefit efforts.

Conflict management.

Whether major or minor, barriers or challenges are an inevitable part of transformational change, as was the case at HMC, MIT, and UT-Austin. To ensure that these barriers do not derail efforts, it is important to make sure that leaders associated with initiatives know how to manage conflict. At HMC, for instance, it was important for faculty to address scheduling conflicts to ensure that faculty outside of computer science remained supportive of the initiatives. At MIT, it was important that faculty knew that the best approach to handling the protests and concerns of faculty and students who were not supportive of the TEAL format was by going through the department heads. At UT-Austin, the staff of EOE and WEP had to develop strategies for dealing with the challenging aspects of fundraising. If these issues had not been handled appropriately, the outcomes of the initiatives might not have been as successful.

Ability to conduct comprehensive assessment and evaluation.

As discussed earlier, assessment and evaluation were critical to the success of the initiatives at each institution, as the results impacted other strategies. With this in mind, it is important that leaders associated with initiatives be able to conduct and/or designate qualified individuals to conduct comprehensive assessment and evaluation. At HMC, the faculty seemed to have worked cooperatively to assess and evaluate each of the three major initiatives. At MIT, someone was hired specifically to focus on assessment of the TEAL format for teaching introductory physics courses, and at UT-Austin, the staff conducted the assessment. Leaders must decide whether the competencies of the individuals associated with the initiatives are adequate or if hiring assessment professionals is a better option. If staff lack assessment/evaluation skills but funding is too prohibitive to hire a professional, another option might be collaborations with staff in institutional research offices or graduate assistants in research areas. Another option might be to provide training conducted by professionals from institutional research or a related area.

Initiative and passion.

As described in the findings, the leaders associated with each of the initiatives were passionate about the initiatives and highly motivated to achieve their goals. As an example, at HMC the faculty in the department initiated the changes in the department without having been prompted to do so by college administrators. In addition, the president and some of the faculty were motivated to put in extra effort by their own personal experiences as females in male-dominated professions. In the same way, at MIT the faculty and administrators in physics, who were associated with the flexible major option, the TEAL initiative, and other departmental initiatives, took it upon themselves to find solutions to long-standing issues that the department faced. Like the faculty at HMC, several of the faculty members at MIT were motivated by personal experiences in their backgrounds that made them more aware of the issues that underrepresented, low-income, and first-generation college students face. This was also the case with the directors of EOE and WEP. Although initiative and passion are perhaps more difficult to assess, it is worth considering how one might identify these qualities in team members or in prospective employees.

Pedagogy and academic policies.

In addition to the more process-oriented implications from this study, numerous documents revealed useful insights for pedagogy and academic policies in and beyond the STEM disciplines. These insights may be helpful to faculty and administrators.

***Breadth-first course content*.**

One such insight relates to the breadth-first introductory computer science course at HMC. By changing the emphasis in the course, faculty were able to provide an overview of computer science for those with limited exposure to the discipline, which proved to be an important recruitment strategy, for all students, not just women. Interestingly, they were able to do so without compromising the students' ability to proceed with the follow-up courses if they chose to become computer science majors. This has important implications, because there may be an assumption that students are already familiar with what computer scientists, physicists, and engineers do, but their knowledge may not be adequately informed. As a result, many students may conclude that their interests and skills are not aligned with these types of majors. This is also important because some faculty and administrators provide breadth-first activities at the expense of providing rigorous activities that equip students with the skills necessary to be successful in subsequent courses. It seems a balance between the two strategies is important.

Common core curriculum.

The breadth-first course content relates to another important insight about the common core requirements at HMC and the general Institute requirements (GIRs) at MIT. According to the documents collected at these institutions, computer science and physics are not typical core requirements at other institutions. Including these courses in the common requirements at these two institutions allowed students exposure to these disciplines and likely had some influence on the increase in students majoring in these disciplines, which makes it an option worth considering at other institutions. If this is not a viable option at other institutions, the approach that UT-Austin took in providing "signature courses" that were designed to provide exposure to a variety of disciplines, may be a more feasible option also worth pursuing.

Teaching students their roles in group study.

Another important insight from this study relates to student study or task groups, such as those in the introductory computer science course at HMC and the introductory physics course at MIT. Although these types of groups are promoted heavily in the literature, there does not seem to be as much attention placed on training students about how to work in these groups. The documents from HMC and MIT related to assessment and evaluation revealed that without this training, the students with stronger backgrounds tended to assume responsibility for the work, minimizing the learning outcomes for the other students and discouraging their persistence in the discipline. In response to these evaluations, faculty at both institutions revised their efforts to include an intentional effort to make students more aware of their roles in the study group and how they could learn from each other. This is important for faculty in any discipline to note when implementing similar student task groups.

General practice.

This study also has implications for general practice. Documents at each of the institutions revealed an interesting phenomenon that should challenge traditional approaches in a variety of fields. Attempts to impact student learning for all students had an added effect of attracting women and/or URMs, and vice versa. For example, at HMC and MIT, the goal of better learning outcomes for all students in introductory computer science and physics courses ended up attracting more women and/or URMs as computer science and physics majors. Alternatively, at MIT the Office of Minority Education provides tutorial services that are designed with women and minority students in mind but are offered to and utilized by students from many backgrounds, including males and White students. The implication, then, is that innovative thinking about how to impact the enrollment and graduation rates of women and URMs in the STEM disciplines should not be limited to certain populations or the departments and areas that have traditionally served those populations.

Another insight from the study involves addressing the psychological issues that women and URMs face. As discussed in the cross-case analysis, faculty and staff in each department and school took time to encourage women and/or URMs that many of the issues they faced – imposter syndrome, stereotype threat, and isolation, for example – were common and valid issues, and they gave them practical advice for how to overcome these obstacles. Although the advice varied, several documents at each institution revealed that at the root of the advice was an emphasis on excellence. In other words, the students were encouraged to press through their issues by striving for academic excellence. This has implications for anyone who works with underrepresented student populations. Validating the issues that these populations face, as noted in the documents from each institution, seems important, as is fostering an environment in which these students feel empowered to achieve their fullest academic potential. Although offices that provide services specifically for underrepresented student populations likely attend to these students' psychological needs, it is probably helpful if the students get this sort of attention from faculty and staff in their major departments/schools, as well. The staff member from MIT interviewed for this study called this "triaging."

Future Research

As much as this study illuminated the various strategies that model STEM departments and schools at elite institutions utilized to promote initiatives that proved to be successful, it also stirred up other questions that need to be answered. Answering these questions will help determine if there are other strategies that ensure that changes designed to broaden participation among women and URMs in the STEM are systemic and whether the strategies utilized at these three institutions are transferable to other less selective institutions that do not have as many resources.

Transformational change at less-selective institutions.

The women and URMs in the model departments and school of this study were considered top achievers among their peers, which was important to this study because women and URMs with strong academic backgrounds are seldom studied. However, additional research needs to be focused on implementation processes that have been successful in attracting and preparing the average student who may not have as strong of a background in math and science, subjects which are pre-requisites for success in the STEM disciplines.

Focus on awareness of strategies.

A focus on developing strategies for successful implementation also leads one to ponder how familiar faculty, staff, and administrators who lead or are considering STEM initiatives are with models of organizational change and whether they utilize these models when developing initiatives. A related issue is whether the strategies utilized by those who develop initiatives for women and URMs in the STEM align with senior administrators' views of what it takes to secure their buy-in.

Barriers.

An additional area for future research is on what those tasked with developing initiatives for women and URMs in the STEM perceive as barriers to the implementation of their initiatives, what they draw on to react to these barriers, and how their reactions to the barriers influence the success of their initiatives. In addition, it would be important to note how barriers differ depending on institutional type.

Socioeconomic status and scholarships.

Even though the documents in this study, including the interview transcripts, did not reference the role that financial aid, scholarships, and grants played in attracting women and URMs to their departments/school, this is another important area for future research. Several elite institutions in recent years have developed financial aid packages that allow qualified students from low-income backgrounds to attend without accumulating student loan debt. Studying whether these programs have had an impact on students majoring in the STEM disciplines would provide insight into other strategies that may factor into the success that the institutions in this study and others have had with regard to enrolling and graduating women and URMs.

Research in each of these areas will contribute to an understanding of how faculty, staff, and administrators can take responsibility for their roles in promoting inclusive excellence by engaging in systemic efforts to increase the enrollment and graduation rates of women and URMs, instead of engaging in isolated or deficit approaches. Ultimately this has the potential to transform the culture of the STEM disciplines and perhaps broaden participation of students from all backgrounds.

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APPENDIX A: COLLECTED DOCUMENTS

A1. Harvey Mudd College – Department of Computer Science

Document Type	*Abbreviation*	*# of Documents*
College Information on Website	CIW	4
Conference Paper	CP	2
College Report	CR	9
Department Information on Website	DIW	10
External College News Article	ECNA	1
External College Review Site	ECRS	1
External Report	ER	1
Grant Information	GI	11
Industry Blog	IB	6
Industry News Article	INA	6
Journal Article	JA	4
Journal Article Ad	JAD	1
News Article	NA	9
Participant Interview Transcript	PIT	2
Radio News Transcript	RNT	4
Total		71

I.D. Number	Reference
HMC-01-CR	Adolph, S., Cave, R., Cha, P., Daub, W., Erlinger, M., Groves, J., Saeta, P., Su, F., Sullivan, L. & Townsend, J. (2008, September 24). A proposal for a revision of the common core. Retrieved from https://www.hmc.edu/dean-of-faculty/wp-content/uploads/sites/11/2013/12/SVCC-proposal-revised.pdf.
HMC-02-IB	Alvarado, C. (2014). First year women @ GHC. *Christine Alvarado Blog*. Retrieved from https://sites.google.com/a/eng.ucsd.edu/alvarado/projects/first-year-women-ghc.
HMC-03-JA	Alvarado, C. & Dodds, Z. (2010). Women in CS: An evaluation of three promising practices. In *Proceedings of Symposium on Computer Science Education*, p. 57-61. March 10–13, 2010, Milwaukee, Wisconsin.

I.D. Number	Reference
HMC-04-JA	Alvarado, C., Dodds, Z. & Libeskind-Hadas, R. (2012). Increasing women's participation in computing at Harvey Mudd College. *ACM Inroads*, 3(4), 55-64.
HMC-05-JA	Alvarado, C., Dodds, Z. Kuenning, G. & Libeskind-Hadas, R. (2007). Breadth-first CS 1 for scientists. Paper presented at the 12th Annual Conference on Innovation and Technology in Computer Science Education. Dundee, Scotland UK, June 23-27, 2007.
HMC-06-DIW	Alvarado, C., Dodds, Z. Kuenning, G. & Libeskind-Hadas, R. (2014). Introduction to CS for all. Retrieved from www.cs.hmc.edu/csforall/.
HMC-07-JA	Alvarado, C. & Judson, E. (2014, March). Using targeted conferences to recruit women into computer science. *Communications of the ACM*, 57(3), 70-77.
HMC-08-CP	Alvarado, C., Lee, C. B., & Gillespie, G. (2014). *New CSI pedagogies and curriculum, the same success factors?* Proceedings of the 45th Technical Symposium on Computer Science Education, New York, NY, 379-384.
HMC-09-INA	Cassidy, M. (2013, December 18). Silicon Valley's top 10 feeder colleges – Stanford, yes, but Harvey Mudd? *Silicon Beat*. Retrieved from http://www.siliconbeat.com/2013/12/18/ silicon-valleys-to-10-feeder-colleges-stanford-yes-but-harvey-mudd/.
HMC-10-INA	Cohoon, J. M. (2010). Harvey Mudd College's successful systemic approach (case study 2): Attracting students through an engaging introductory computing curriculum. *NCWIT.org*. Retrieved from http://management.fortune.cnn.com/2012/10/05/ maria-klawe-harvey-mudd/
HMC-11-PIT	Davis, T. (2014). Participant 1 transcript. Unpublished raw data.
HMC-12-PIT	Davis, T. (2014). Participant 2 transcript. Unpublished raw data.
HMC-13-CP	Dodds, Z., Libeskind-Hadas, R., Alvarado, C. & Kuenning, G. (2008). Evaluating a breadth-first CS 1 for scientists. In Proceedings of SIGCSE, March 12-15, 2008. Portland, OR.
HMC-14-NA	Hafner, K. (2012, April 2). Giving women the access code. *New York Times*. Retrieved from http://www.nytimes.com/ 2012/04/03/science/giving-women-the-accesscode.html?_ r=0&pagewanted=print.
HMC-15-NA	Haines, A. (2011, December 12). How one college president is breaking down barriers for women in tech. *Forbes.com*. Retrieved from http://www.forbes.com/sites/ 85broads/2011/ 12/12/how-one-college-president-is-breaking-down-barriers-for-women-in-tech/.
HMC-16-CR	Harvey Mudd College. (2006). Thoughts for Harvey Mudd College's strategic plan: 2005-2006. Retrieved from www.cs.hmc.edu/hmc2020society/.

I.D. Number	Reference
HMC-04-JA	Alvarado, C., Dodds, Z. & Libeskind-Hadas, R. (2012). Increasing women's participation in computing at Harvey Mudd College. *ACM Inroads*, 3(4), 55-64.
HMC-17-CR	Harvey Mudd College. (2007). HMC 2020: Envisioning the future. Retrieved from https://www.hmc.edu/about-hmc/ mission-vision/
HMC-18-CR	Harvey Mudd College. (2007). Strategic planning initiative. Retrieved from http://www.hmc.edu/about1/administrativeoffices/ Officeofthepresident1…nding/fromoldsite/hmc2020envisioningthe future1/planning.html#process.
HMC-19-CR	Harvey Mudd College. (2010). Faculty notebook. Retrieved from [complete]
HMC-20-CR	Harvey Mudd College. (2010, December). *Harvey Mudd College educational effectiveness review: Report to the Western Association of Schools and Colleges Accrediting Commission for Senior Colleges and Universities*. Retrieved from www.hmc.edu/dean-of-faculty/wp-content/uploads/ sites/11/2013/12/hmc-eer-december-7-2010.pdf.
HMC-21-CR	Harvey Mudd College. (2011). *The Harvey Mudd College reappointment, promotion, and tenure committee: Recommended practices*. Retrieved from http://www.hmc.edu/about/ administrativeoffices/deanoffaculty1/RPT%20Recommended-Practices.html.
HMC-22-CR	Harvey Mudd College. (2012, Fall/Winter). *Harvey Mudd College academic year 2011-2012 annual report*. Retrieved from www.hmc.edu.
HMC-23-CIW	Harvey Mudd College. (2013). A bold investment: The President's Scholars Program. Retrieved from www.hmc.edu/invest/fund-a Student-scholar.shtml.
HMC-24-JAD	Harvey Mudd College. (2013, October 15). Harvey Mudd College – tenure track assistant professorships (job posting). *The Journal of Black in Higher Education*. Retrieved October 27, 2013 from http://www.jbhe.com/2013/10/harvey-mudd-college-tenure-track-assistant-professorships-computer-science/.
HMC-25-CR	Harvey Mudd College. (2014). Enrollment of minorities and women. Retrieved from https://www.hmc.edu/dean-of-faculty/institutional-research/institutional-statistics/enrollment-of-minorities-and-women/
HMC-26-CIW	Harvey Mudd College. (2014). *Fast facts*. Retrieved from https://www.hmc.edu/about-hmc/fast-facts/.
HMC-27-CIW	Harvey Mudd College. (2014). *Harvey Mudd College: Admission and financial ai*d. Retrieved from http://newwww.hmc.edu/ admission/discover/#link_2

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HMC-04-JA	Alvarado, C., Dodds, Z. & Libeskind-Hadas, R. (2012). Increasing women's participation in computing at Harvey Mudd College. *ACM Inroads*, 3(4), 55-64.
HMC-28-GI	Harvey Mudd College. (2014). Recent faculty grants. Retrieved from https://www.hmc.edu/research/grant-resources-administration/recent-faculty-grants/.
HMC-29-DIW	Harvey Mudd College, Department of Computer Science. (2014). Computer Science Major: Overview. Retrieved from https://www.cs.hmc.edu/program/ cs-major.
HMC-30-DIW	Harvey Mudd College, Department of Computer Science. (2014). Computing @ Harvey Mudd. Retrieved from http://newwww.hmc.edu/admission/2014/02/ computing-harvey-mudd/.
HMC-31-DIW	Harvey Mudd College, Department of Computer Science. (2014). Faculty Positions: Tenure-track assistant professorships. Retrieved from http://www.cs.hmc.edu/ faculty-positions/.
HMC-32-DIW	Harvey Mudd College, Department of Computer Science. (2014). Goals, innovations, results. Retrieved from http://www.cs.hmc.edu/goals-innovations-results/.
HMC-33-DIW	Harvey Mudd College, Department of Computer Science. (2014). Introductory computer science at Harvey Mudd College. Retrieved from http://www.cs.hmc.edu/ ~alvarado/IntroCS.html.
HMC-34-DIW	Harvey Mudd College, Department of Computer Science. (2014). People: Faculty and staff. Retrieved from http://www.cs.hmc.edu/people/.
HMC-35-DIW	Harvey Mudd College, Department of Computer Science. (2014). Research experience for undergraduates – 2014. Retrieved from https://www.cs.hmc.edu/reu/.
HMC-36-DIW	Harvey Mudd College, Department of Computer Science. (2014). Research projects for summer 2014. Retrieved from https://www.cs.hmc.edu/research/projects.
HMC-37-DIW	Harvey Mudd College, Department of Computer Science. (2014). Welcome to the Harvey Mudd "Introduction to Computer Science" course web page. Retrieved from https://www.cs.hmc.edu/twiki/bin/view/ModularCS1/ edu/twiki/bin/view/ModularCS1/WebHome?template=viewprint.
HMC-38-IB	Ibaraki, S. (2012, December 3). Chat Dr. Maria Klawe, pioneering world-renowned computer scientist and executive leader, shares her past to current career years – Part 1. Canadian IT Manager's Blog. Retrieved from http://www.stephenibaraki. com/cips/v0712/maria_klawe_07_2012_part1.html

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HMC-04-JA	Alvarado, C., Dodds, Z. & Libeskind-Hadas, R. (2012). Increasing women's participation in computing at Harvey Mudd College. *ACM Inroads*, 3(4), 55-64.
HMC-39-IB	Ibaraki, S. (2012, December 3). Chat Dr. Maria Klawe, pioneering world-renowned computer scientist and executive leader, shares her past to current career years – Part 2. Canadian IT Manager's Blog. Retrieved from http://blogs.technet. com/b/cdnitmanagers/archive/2012/12/03/chat-dr-maria-klawe-pioneering-world-renowned-computer-scientist-and-executive-leader-shares-her-past-to-current-career-years-part-2.aspx
HMC-40-ER	Karukstis, K. K. & Hensel, N. (2010). *Transformative Research at predominately undergraduate institutions*. Washington, DC: Council on Undergraduate Research.
HMC-41-RNT	Kaufman, W. (2013, May 1). How one college is closing the science gender gap. NPR. Retrieved from http://www.npr.org/ blogs/alltechconsidered/2013/05/01/178810710/How-One-College-Is-Closing-The-Tech-Gender-Gap.
HMC-42-NA	Kelly, H. (2013, May 27). Google's quest to get more women in tech. *CNN Online*. Retrieved from http://www.cnn.com/ 2013/05/24/tech/innovation/women-at-ioio/index.html? iref=allsearch.
HMC-43-INA	Klawe, M. (2013, March). Increasing female participation in computing: The Harvey Mudd College story. *Computer*. Retrieved from [complete]
HMC-44-CIW	Klawe, M. (2014). Letter from the president of Harvey Mudd College on women in computing. Retrieved from http://www.hmc.edu.
HMC-45-NA	Klawe, M. (2014). Look what happens when STEM professors teach writing. Forbes. Retrieved from http://www.forbes.com/sites/mariaklawe/2014/04/30/why-stem-professors-can-teach-anything-even-writing/ Page.
HMC-46-NA	Kowitt, B. (2012, October 5). How to get girls psyched out about computer science. CNNMoney. Retrieved from http://management.fortune.cnn.com/2012/10/05/ maria-klawe-harvey-mudd/.
HMC-47-NA	Levy, A. (2011, September 22). A campus champion for women in computer science. *Businessweek*. Retrieved from www.businessweek.com/magazine/a-campus-champion-for-women-in-computer-science-09222011.html.
HMC-48-NA	Levy, A. (2011, September 23). Klawe turns Harvey Mudd College into haven for women in tech. Bloomberg Online. Retrieved from http://www.bloomberg.com/news/print /2011-09-23/klawe-turns-harvey-mudd-college-into-haven-for-women-in-tech.html.

I.D. Number	Reference
HMC-04-JA	Alvarado, C., Dodds, Z. & Libeskind-Hadas, R. (2012). Increasing women's participation in computing at Harvey Mudd College. *ACM Inroads*, 3(4), 55-64.
HMC-49-NA	Lewin, T. (2012, September 16). Online mentors to guide women into the sciences. *New York Times* (online). Retrieved from http://www.nytimes.com/2012/09/17/ education/online-mentoring-program-to-encourage-women-in-sciences.html?pagewanted=print.
HMC-50-IB	Libeskind-Hadas, R. (2014). Computer science for non-majors. *Computing Commuting Consortium* (CCC) Blog. Retrieved from http://www.cccblog.org/2014/02/17/computer-science-for-non-majors/.
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Document Type	*Abbreviation*	*# of Documents*
College Blog	CB	3
College News Article	CNA	21
College Report	CR	22
Department Information on Website	DIW	4
External College Review Site	ECRS	2
Facebook Page	FB	1
Industry Blog	IB	2
Institute Information on Website	IIW	21
Industry Keynote Address	IKA	1
Industry News Article	INA	10
Industry Report	IR	1
Industry Wiki Page	IW	1
Journal Article	JA	5
News Article	NA	4
Participant Interview Transcript	PIT	3
Personal Blog	PB	1

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A3. University of Texas Austin – Cockrell School of Engineering

Document Type	*Abbreviation*	*# of Document*
College Information on Website	CIW	18
College News Article	CNA	5
Conference Paper	CP	3
College Report	CR	8
External College Review Site	ECRS	1
External Organization Website	EOW	2
External Report	ER	1
Grant Information	GI	1
Industry Report	IR	1
LinkedIn	LI	1
News Article	NA	5
Participant Interview Transcript	PIT	2
State Government Website	SGW	4
University Dissertation	UD	1
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UTA-08-PIT	Davis, T. (2014). Participant 8 transcript. Unpublished raw data.
UTA-09-LI	Dominguez, E. (2014) Enrique Dominguez. [LinkedIn page] Retrieved from http://www.linkedin.com/pub/enrique-dominguez/4/2a0/940.
UTA-10-EOW	Edexcelencia. (2014). Equal Opportunity in Engineering Program (EOE). Retrieved from http://www.edexcelencia.org/program/ Equal-opportunity-engineering-program-eoe.
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UTA-12-NA	Jaschik, S. (2013, June 25). Did the court punt? Or not? *Inside Higher Ed*.
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UTA-31-UR	UT Austin. (2008). State of the Cockrell School. Retrieved from http://archive.is/NjnJG.
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UTA-35-UIW	UT Austin. (2014). Experts Guide: Andrea Ogilvie. Retrieved from http://www.utexas.edu/experts/andrea_ogilvie.
UTA-36-UIW	UT Austin. (2014). A four year graduation help desk. Retrieved from http://www.utexas.edu/enrollment-management/messages/ four-year-graduation-help-desk.
UTA-37-UIW	UT Austin. (2014). Registered student organization database. Retrieved from http://deanofstudents.utexas.edu/sa/vieworgs.php.
UTA-38-UR	UT Austin. (2014, January). The University of Texas at Austin accountability report. Retrieved from http://www.txhighereddata.org/Interactive/Accountability/ UNIV_Complete_PDF.cfm?FICE=003658.
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UTA-46-CNA	UT Austin, Cockrell School of Engineering. (2013). A strong finish to the fall semester. Retrieved from http://www.engr.utexas.edu/ about/dean/messages/7720-strong-finish-to-fall-semester.
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UTA-50-CIW	UT Austin, Cockrell School of Engineering. (2014). Diversity. Retrieved from http://www.engr.utexas.edu/about/diversity.
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UTA-53-CIW	UT Austin, Cockrell School of Engineering. (n.d.). First-year interest groups. Retrieved from http://www.engr.utexas.edu/eoe/academic/figs.
UTA-54-CIW	UT Austin, Cockrell School of Engineering, Engineering Student Life. (2014). Learn about student organizations. Retrieved from http://www.engr.utexas.edu/studentlife/learn.
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UTA-59-CR	UT Austin, Cockrell School of Engineering, Equal Opportunity in Engineering Program. (2014). Impact data. Retrieved from http://www.engr.utexas.edu/eoe/about/impact.
UTA-60-CNA	UT Austin, Cockrell School of Engineering, Equal Opportunity in Engineering Program. (2014). News. Retrieved from http://www.Engr.utexas.edu/eoe/news.
UTA-61-CIW	UT Austin, Cockrell School of Engineering, Equal Opportunity in Engineering Program. (2014). Overview. Retrieved from www.engr.utexas.edu/eoe/.
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UTA-64-CIW	UT Austin, Cockrell School of Engineering, Women in Engineering Program. (2014). Corporate partners. Retrieved from http://www.Engr.utexas.edu/wep/support/corporate.
UTA-65-CIW	UT Austin, Cockrell School of Engineering, Women in Engineering Program. (2014). Mentors and volunteers. Retrieved from https://www.engr.utexas.edu/wep/mentors.
UTA-66-CIW	UT Austin, Cockrell School of Engineering, Women in Engineering Program, UT Austin. (2014). Our partners. Retrieved from http://www.engr.Utexas.edu/wep/partners.
UTA-67-CIW	UT Austin, Cockrell School of Engineering, Women in Engineering Program, UT Austin. (2014). Staff. Retrieved from https://www.engr.Utexas.edu/wep/about/52-staff.
UTA-68-CIW	UT Austin, Cockrell School of Engineering, Women in Engineering Program, UT Austin. (2014). Upcoming events. Retrieved from http://www.engr.utexas.edu/wep/.
UTA-69-UIW	UT Austin. Division of Diversity and Community Engagement. (2014). Longhorn center for academic excellence. Retrieved from http://ddce.utexas.edu/academicenter/gateway-scholars/.
UTA-70-UIW	UT Austin, Human Resources. (2014). The University of Texas at Austin Job Posting: Program Coordinator. Retrieved from https://utdirect.utexas.edu/apps/hr/jobs/nlogon/140522018105.
UTA-71-CIW	UTSHPE. (2014). Current EOE advisor and past EOE advisor. Retrieved from http://www.utshpe.org/#!advisor/c1xkm.

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UTA-72-UR	The University of Texas System. (2013, November). Task force on engineering education for Texas in the 21st century: Final report. Retrieved from http://www.utsystem.edu/sites/utsfiles/news/assets/engineering_taskforce_final.pdf.
UTA-73-NA	White, S. & Jespersen, L. (2013, October 7). More women study at UT's Cockrell School of Engineering than ever before. *The Daily Texan Online*.

APPENDIX B:
Study Participant Information

B1. Participation Letter

Invitation to participate in research study of transformational change in the STEM disciplines

Dear ___________________:

I am writing to invite your participation in a research study undertaken at the University of South Carolina to explore transformational change in the STEM disciplines, with particular regard to initiatives that have demonstrated success at increasing the graduation rates of underrepresented student populations. The study purpose is to gain a better understanding of strategies and approaches to implementing research-based initiatives that are sustainable and systemic.

Your participation in this study would be entirely voluntary and would consist of a semi-structured phone interview lasting approximately an hour. With your permission, this interview would be taped and transcribed for accuracy of information. You would be asked a series of questions about strategies utilized in your department/school to implement programs and activities that have contributed to an increase in the graduation rates of underrepresented student populations. You would not be required to answer the questions and could choose not to answer any question for any reason. You would then be invited to review the resulting transcribed interview and to correct any inaccuracies. All study findings would be reported in the aggregate to protect individual anonymity to the fullest extent possible.

At any time during the interview, you would be free to withdraw your consent and to discontinue participation in the study without fear of penalty. In such an instance, all records of your participation would be destroyed.

Your participation would contribute valuable information that could inform collective understanding of transformational change in the STEM disciplines and the strategies necessary to cultivate inclusive excellence. The information might also assist faculty and administrators who are interested in pursuing initiatives that aim to broaden participation of underrepresented student populations in the STEM disciplines, in addition to those in other fields who are likewise interested in broadening participation. There are no known risks associated with study participation beyond those that might be experienced by reflecting on your perceptions of the strategies utilized within your department/school to implement programs aimed at increasing the graduation rates of underrepresented student groups.

If you agree to participate, I will follow up with an email to discuss possible interview times that would be most convenient for your schedule.

Please note that this study has been reviewed and approved through the Institutional Research Board at the University of South Carolina. (See the attached correspondence.) If you have any questions regarding this study or would like additional information about participation, please do not hesitate to contact me daviste5@mailbox.sc.edu.

Thank you in advance for your consideration of this invitation.

Sincerely,

Telesia E. Davis, Principal Investigator
and Ph.D. Candidate
Educational Leadership & Policies
College of Education
University of South Carolina

B2. IRB Approval Letter

UNIVERSITY OF
SOUTH CAROLINA

OFFICE OF RESEARCH COMPLIANCE

April 24, 2014

Ms. Telesia Davis
College of Education
Education
Wardlaw College - 115B
Columbia, SC 29208

Re: Pro00030724
Study Title: *Transforming the Culture of the STEM Fields: A Multiple Case Study of Successful Strategies for Inclusive Excellence*

FYI: University of South Carolina Assurance number: FWA 00000404 / IRB Registration number: 00000240

Dear Ms. Davis:

In accordance with 45 CFR 46.101(b)(2 & 4), the referenced study received an exemption from Human Research Subject Regulations on **4/21/2014**. No further action or Institutional Review Board (IRB) oversight is required, as long as the project remains the same. However, you must inform this office of any changes in procedures involving human subjects. Changes to the current research protocol could result in a reclassification of the study and further review by the IRB.

Because this project was determined to be exempt from further IRB oversight, consent document(s), if applicable, are not stamped with an expiration date.

Research related records should be retained for a minimum of three years after termination of the study.

The Office of Research Compliance is an administrative office that supports the USC Institutional Review Board. If you have questions, please contact Arlene McWhorter at arlenem@sc.edu or (803) 777-7095.

Sincerely,

Lisa M. Johnson
IRB Manager

University of South Carolina • Columbia, South Carolina 29208 • 803-777-5458

An Equal Opportunity Institution

B3. Interview Protocol

Articulation of Rationale & Goals

1. What were the circumstances or events that prompted faculty in the computer science department, and in particular, you, to pursue the various programs that were implemented within the department?
2. What strategies did you and/or the other faculty utilize to determine the best approach for addressing these circumstances? (Was this discussed in faculty meetings, during casual conversations?)
3. Can you explain whether this process was a typical approach for the computer science department, or did this represent a new way of doing things?
4. I'm curious. You were an assistant professor and new to college at that time. How did these circumstances contribute to your approach?

Buy-In and Advocacy from Senior Leadership

5. As you began to plan for some sort of change, at what point, if at any, did you begin to consider the people from whom you would need to secure buy-in?
6. How did you go about determining who these key people would be?
7. What strategies did you utilize to secure buy-in from the people you determined would be most helpful to your cause?

Collaborative Leadership at Multiple Levels

8. Who were all the people involved with implementing these programs (e.g., specific faculty members, administrators, students, etc.)
9. Please describe how these people were involved and the contributions they made.

Flexible Vision

10. How did you arrive at a vision or goals for implementing change in the School of Engineering?
11. In what ways and why did this vision change, if at all, throughout the process?

Professional Development

12. What, if any, professional development or training was necessary to ensure the success of planned initiatives?
13. Who conducted this training and what was the schedule like? (e.g., one-time training, ongoing, etc.)

Empowering Settings for Underrepresented Groups

14. In what ways, if any, did the changes contribute to establishing a setting in which underrepresented students felt more confident about their ability to succeed in their major? (e.g. group activities and study groups, peer mentoring, etc.)
15. What evidence do you have of this? (Not necessary)

Visible Action Staged Over Time

16. Were there other specific visible actions or initiatives, both formal and informal, that were pursued in an effort to increase the participation and graduation rates of underrepresented groups?
17. How and when did students, faculty, and staff, both internal to and external to the department, become aware that the department was going to implement these initiatives?

Continuous Assessment and Evaluation

18. What impact, if any, did assessment and evaluation, both formal and informal, play in the success of the initiatives?
19. How did you use the results of your assessment and evaluation? (May not need to ask this question.)

Barriers

20. What barriers, if any, did you and the faculty in the department face with implementing these new programs, and how did you overcome them?

Other

21. What are the factors you think most contributed to the success of these new programs in your department? Please explain.
22. Is there any other information you think I should know about the process involved with implementing these programs?
23. Are there any internal and/or public documents that you could point me to that are not available on the Harvey Mudd website that would corroborate the information you shared with me today?
24. Do you have suggestions for other people (faculty, staff, administrators, and students) that I should interview?

APPENDIX C: SUMMARY OF FINDINGS

Harvey Mudd College – Department of Computer Science

Document Type	*Abbreviation*	*# of Documents*
College Information on Website	CIW	4
Conference Paper	CP	2
College Report	CR	9
Department Information on Website	DIW	10
External College News Article	ECNA	1
External College Review Site	ECRS	1
External Report	ER	1
Grant Information	GI	11
Industry Blog	IB	6
Industry News Article	INA	6
Journal Article	JA	4
Journal Article Ad	JAD	1
News Article	NA	9
Participant Interview Transcript	PIT	2
Radio News Transcript	RNT	4
Total		71

Strategy 1: Clear understanding and articulation of the rationale for change		
Finding	Examples/Evidence	Collected Documents
Thorough research about why girls/women, in general, are not attracted to the STEM disciplines	• In numerous articles and interviews – both scholarly and news – faculty and administrators shared what the research says. • Both interview participants detailed the research efforts as part of program implementation	• CIW – 44 • CP – 7, 8 • IB – 67, 71 • INA – 43, 66 • JA – 3, 4, 5, 7 • NA – 14, 46 • PIT – 11, 12 • RNT – 68 • PIT – 11, 12
Research about what other institutions were doing to attract females to computer science	• During interviews, faculty members and administrators referenced looking around to see what other people were doing.	• PIT – 11, 12

Evidence that they also studied their own students to determine how they were motivated	• Faculty tracked participation rates for each initiative and based their approaches on this data – identified three groups of students – majors, major-considerers, and CS-interested • Faculty captured experiences with introductory course both before and after initiatives were introduced	• JA – 3 • JA – 4, 5
Used research, initiative goals, and personal experiences to tell relatable stories in clear, concise, and consistent manner	• Klawe told stories in articles and speeches – These likely increased momentum and buy-in within the CS department and from external donors.	• ECNA – 65 • IB – 41, 71 • INA - 66 • NA – 14, 15, 46, 69 • RNT – 53, 68
Strategy 2: Buy-In and Advocacy from Senior Leadership		
Finding	Examples/Evidence	Collected Documents
President as advocate	• Both participants indicated that Klawe was "cheerleader" and strong advocate for the initiatives • Interviews with and articles about Klawe reveal her advocacy • Blogs and journal articles reference specific contributions (e.g., 5K funding for GHC,	• PIT – 11, 12 • ECNA – 65 • CIW – 44 • CR – 22 • IB – 38, 39, 67 • INA - 66 • NA – 14, 15, 46, 47, 48, 69 • RNT – 53, 54, 68 • IB – 2 • JA – 4
Faculty incentives that support goals	• Participants 1 and 2 indicated that Klawe was going to reward their efforts (specific efforts not mentioned) • HMC guidelines on tenure and promotion reward excellence in teaching • Participant interviews referenced hiring of female and minority faculty in the department and throughout the College and described hiring process. • Participant 2 referenced hiring of dean for diversity in both the dean of students office and the dean of the faculty's office.	• PIT – 11, 12 • CR – 19, 21 • DIW – 30 • JAD – 24 • PIT – 11, 12 • PIT - 12

Support from previous and current chair of the department	• Participant 1 mentioned Erlinger (previous chair) • Journal articles from current chair are evidence of support and interest in initiatives	• PIT - 11 • IB – 50 • JA – 4, 5
External support and advocacy from industry leaders	• Participant 2, news article, and radio interview referenced support of industry leaders (e.g., Sheryl Sandberg, Alan Eustace)	• PIT – 12 • NA – 47 • RNT - 54
Strategy 3: Collaborative Leadership at Multiple Levels		
Finding	Examples/Evidence	Collected Documents
Interdisciplinary collaboration	• Specific references to collaborations with biology faculty (e.g., journal articles and department web pages)	• GI - 55 • INA – 51 • NA - 45 • PIT - 12
Collaborations across departments	• Interview participants and several documents referenced collaborations with admissions, advancement, president's office, etc. • Interview participants and several documents referenced campus culture of collaboration	• CR – 18, 20, 22 • IB – 2 • NA - 47 • PIT – 11, 12 • CR – 16, 17, 18 • PIT – 11, 12 • HMC Educational Effectiveness Review – 50 • Strategic Planning Initiative - 75
Collaborations across institutions	• Specific references to collaborations with other institutions - specifically, an NSF grant to collaborate with K-12 and Higher Ed institutions	• CP – 8 • CIW – 60 • IB – 50 • GI – 58, 60, 62 • PIT - 12
Strategy 4: Flexible Vision		
Finding	Examples/Evidence	Collected Documents
Adding new programs or initiatives to reflect change in vision	• Discovered stereotypical "Black" (experienced programmers) group participants in the gold course, so developed an approach for addressing how they intimidated other students	• CP – 13 • PIT – 12
Revising existing programs to reflect change in vision	• Intention to revise assignments and final-project options	• JA – 5
Supported general philosophy behind flexible vision	• Mentioned the importance of adapting ideas proven elsewhere to local conditions	• JA – 4
Strategy 5: Professional Development		
Finding	Examples/Evidence	Collected Documents

Faculty training	• Interview participant mentioned that faculty training and development resulted from the research necessary for initiatives • Administrator mentioned campus culture that supports ongoing development on quality instruction • NSF Grant abstract addresses training for faculty at other institutions	• PIT – 11 • PIT – 12 • GI – 56, 64
Strategy 6: Planned Attention to the Environment for Women and URMs		
Finding	Examples/Evidence	Collected Documents
Group-based belief system that is inspiring, strengths-based, and focused on connectedness to the communities from which students come	• Students develop projects for middle school students • Participant 2 notes that intro course frames course so that women feel good about being problem-solvers vs. programmers. • GHC evaluations, as shared in blog, indicated that students viewed the conference as positive and motivating. • Surveys and assessment of all three initiatives indicated that all three had a positive impact on students, both women and men. (provided specific results) • Student interviewed for NPR indicated that she wanted little kids to look to her and decide they want to go into computer science like her. • One document indicates that introductory course is supportive but still challenging so that students are prepared for subsequent courses.	• GI – 58 • PIT – 12 • IB – 2 • JA – 3 • RNT – 54 • JA – 4
Pervasive, highly accessible and multifunctional role structure in which students vacillate between learners and mentors in multiple settings that complement the academic program	• Two documents – journal article and interview – mentioned that students play numerous roles in group projects. These documents also point to how students are paired with experienced and inexperienced in research teams.	• PIT – 12 • JA – 4

A multi-faceted, peer-based support system that addresses the holistic needs of the students and that provides a sense of community	• Community formed among students who attended GHC – mentioned in participant interviews • Introductory course structured to meet the needs of students who felt intimidated by those who had more programming experience – referenced in numerous documents and interviews • Exposed students to role-models and successful women in CS • Klawe addressed psychological obstacles (e.g. imposter syndrome and frustration when courses are difficult), as referenced in numerous articles and interviews	• PIT – 11 • IB – 71 • JA – 4 • NA – 47 • PIT – 11, 12 • NA – 69 • CR – 16 • NA – 14, 15, 69, • RNT – 53
Empowering program leadership that is shared, inspirational, highly skilled, and committed to the students	• Several documents indicate that faculty were supportive of students – articles, interviews, journal articles, etc. • Faculty mentors work with inexperienced student research teams	• NA – 14, • PIT – 11, 12 • RNT – 53 • Journal Article – 4
Strategy 7: Visible action that is staged over time		
Finding	Examples/Evidence	Collected Documents
Implementation of Introductory Course	• Staging of the course is referenced in several journal articles, news articles, HMC web pages, industry blogs and participant interviews • Staging of biology course referenced in numerous documents	• CIW – 6, 44 • CP – 13 • DIW – 32, 33, 37 • IB – 50, 71 • INA – 10, 43, 66 • JA – 3, 4, 5, 7 • NA – 14, 47, 69 • PIT – 11, 12 • RNT – 53 • INA – 51
GHC Conference Participation	• Staging of the GHC is referenced in several journal articles, news articles, HMC web pages, industry blogs, and in participant interviews	• CIW – 44 • IB – 50 • INA – 10, 43, 66 • JA – 3, 4 • NA – 14, 47, 69 • PIT – 11, 12 • RNT – 53

Research Experiences	• Staging of research experiences is referenced in several journal articles, news articles, HMC web pages, industry blogs, participant interviews, and grant award abstracts.	• CIW – 44 • DIW – 35, 36 • INA – 43, 66 • GI – 55, 56, 62, 63 • JA – 3, 4 • PIT – 11, 12
Strategy 8: Continuous assessment and evaluation		
Finding	Examples/Evidence	Collected Documents
Comprehensive assessment and evaluation of introductory course	• Several journal articles and HMC web pages provide outcomes from extensive assessment for the introductory course. • Participant interviews reference assessment and evaluation.	• CP – 13 • DIW – 32 • INA – 10 • JA – 5 • PIT – 11, 12
Comprehensive assessment and evaluation of the "Green" introductory course – CS & Biology	• Journal article and Participant 2 provide outcomes from extensive assessment for this course.	• JA – 4 • PIT – 12
Comprehensive assessment and evaluation of GHC experience for students.	• Journal article provides outcomes from extensive assessment for the GHC. • Participant interviews reference assessment and evaluation. • Faculty blog provides copies of survey instruments and summary of outcomes.	• JA - 7 • PIT – 11, 12 • IB – 2
Comprehensive assessment and evaluation of student research experiences	• Journal article provides outcomes from extensive assessment of research experiences • Participant interviews reference assessment and evaluation.	• JA – 4 • PIT – 11, 12
Track participation rates for CS majors	• Journal articles provide detailed information about CS majors	• JA – 3, 4
Revisions based on outcomes	• Participant interviews and journal article reference revisions to programs based on assessment and evaluation.	• JA – 4 • PIT – 11, 12
Outcomes of assessment were motivating and used as leverage to keep going	• Participant 1 referenced the motivational aspect of the assessment outcomes and how faculty used the outcomes as leverage to continue	• PIT – 11
Other Strategies		
Finding	Examples/Evidence	Collected Documents

Initiatives for women evolved out of emphasis on all students	• Participant interviews reference faculty's overarching goal of finding ways to engage all students	• PIT – 11, 12
Initiatives developed in the context of supportive campus environments	• Participant interviews and radio interview provide insight into the culture of the campus and its role in shaping the initiatives	• NA – 49 • PIT – 11, 12 • RNT – 54
Culture of CS department was supportive of innovations in teaching	• Participant interviews cite the culture of the department and its role in shaping the initiatives	• PIT – 11, 12
Funding played a role in success of initiatives	• Participant interviews, faculty blog, grant information, and HMC website indicated that funding played a role in success of initiatives but also highlighted that aspects of the program could be done for little or no additional funding. • Campus resources are referenced in department website document	• CIW – 23, 26, 44 • CR – 22 • GI – 28, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64 • IB – 2 • PIT – 11, 12 • DIW – 30
Personal and professional experiences were part of key leaders motivation for pursuing initiatives	• References to personal experiences were evident in participant interviews and recalled in news articles	• NA – 14, 15, 47, 48, • PIT – 11, 12
Admissions staff played a role in success of enrolling more women at the college.	• Participant 2 referenced the admissions staff	• PIT – 12
Faculty didn't ask permission to implement initiatives, they just took the initiative.	• Participant interviews reveal that faculty took initiative	• PIT – 11, 12
Leaders associated with initiatives were highly skilled and competent in computer science and in project/initiative planning and development	• Participant interviews, news articles, journal articles, industry blogs, and faculty blog reference the skills of leadership (e.g., Klawe, Alvarado, Libeskind-Hadas, faculty in CS department, etc.)	• IB – 38, 50 • GI – 55 • INA – 52 • JA – 4 • NA – 15, 47, 48 • PIT – 11, 12
Communication and marketing (related to articulation of rationale) provided momentum.	• Participant interviews, the HMC annual report, and industry blog discussed the role that communication and marketing played in heightening visibility for CS and HMC.	• CR – 22 • IB – 67 • PIT – 11, 12

Common core gives all students exposure to introductory CS course	• Several documents describe the common core and mention that all students are required to take the introductory CS course.	• CIW – 6 • CR – 1 • DIW – 29, 37 • INA – 3 • Journal Article – 3, 4 • Participant Interview – 12
Selective admissions played a role in the success of initiatives	• Participant 1 alluded to the quality of student at HMC, as do documents on the website	• CIW – 27 • PIT – 11
Barriers		
Scheduling issues around GHC	• Participant 1 referenced having to be creative about scheduling to make sure participants could attend GHC with minimum class interruptions.	• PIT - 11
Dealing with more experienced student programmers in the course section designed for inexperienced programmers	• Participant 2 and several news articles mentioned this as a barrier	• NA – 14, 15, 47, 48, 69 • PIT – 12
Overcoming stereotypes among faculty and students	• Participant 2 mentioned overcoming stereotypes and the perception that standards were lowered to accommodate female CS majors.	• PIT – 12
Student preparation for majoring in computer science	• Participant 2 mentioned that there are very few high schools that have excellent computer science courses.	• PIT – 12
Recruiting African Americans	• Participant 2 explained the challenges of recruiting AA students as CS majors and as students, in general.	• PIT – 12
Resistance to change at other institutions	• Participant 2 described resistance to replicating introductory course on other campuses.	• PIT – 12
Funding (more of a challenge than a barrier)	• Journal article mentioned challenges of raising funds for GHC	• JA – 4

APPENDIX D: SUMMARY OF FINDINGS

Massachusetts Institute of Technology – Department of Physics

Document Type	*Abbreviation*	*# of Documents*
College Blog	CB	3
College News Article	CNA	21
College Report	CR	22
Department Information on Website	DIW	4
External College Review Site	ECRS	2
Facebook Page	FB	1
Document Type	*Abbreviation*	*# of Documents*
Industry Blog	IB	2
Institute Information on Website	IIW	21
Industry Keynote Address	IKA	1
Industry News Article	INA	10
Industry Report	IR	1
Industry Wiki Page	IW	1
Journal Article	JA	5
News Article	NA	4
Participant Interview Transcript	PIT	3
Personal Blog	PB	1
TOTAL		102

Strategy 1: Clear understanding and articulation of the rationale for change		
Finding	Examples	Reference Documents
Declining enrollment in physics.	• One document reveals decline in physics enrollment.	• CR – 31
Physics major didn't provide flexibility that students desired.	• One document discussed this as an issue.	• CR – 31
Physics department was one of few institutions without learning lab for introductory course.	• Several documents mentioned the lack of a learning lab.	• CNA – 7 • CR – 6 • INA – 8, 9, 10 • IR – 27 • JA – 25, 26 • PIT – 21

Several students were missing classes and were not actively engaged in the introductory course work.	• Numerous documents mentioned that students did not find it necessary to come to the introductory physics class.	• CNA - 7 • CR – 6 • IIW – 59 • INA – 8, 9, 10 • JA – 17, 25, 26 • PIT – 21
Introductory physics courses had student failure rates of up to 15 percent.	• Numerous documents mentioned the high failure rates in introductory physics courses.	• CNA – 7 • CR – 6 • IIW – 59 • INA – 8, 9, 10 • IR – 27 • JA – 17, 25, 26 • NA – 87, 90 • PIT – 21
Belcher conducted thorough research before implementing TEAL format, which gave credibility to the TEAL approach.	• Several documents mentioned how Belcher based TEAL format off Beichner's SCALE-Up model in the physics department at NCSU. • Several documents mention the focus on social constructivist theory as part of the research that took place prior to implementation.	• INA – 8, 10 • IR – 27 • NA – 87 • PIT – 21 • JA – 17, 25 • PIT – 21
There used to be a "weeding out" process in physics, rather than a supportive environment.	• One document references the weeding-out process as described by Bertschinger.	• CR – 13
Electromagnetism is a particularly abstract and complex concept to teach by lecture alone.	• Many documents reference the difficulties of learning electromagnetism concepts through lecture.	• CR – 6 • IIW – 59 • INA – 4, 8 • JA – 17, 25, 26 • PIT – 21
Broadening talent pool increases talent.	• One document described how diversity is important to broadening pool of talent.	• DIW – 62
Strategy 2: Buy-In and Advocacy from Senior Leadership		
Finding	Examples	Reference Documents
Senior leadership critical to success of initiatives.	• Numerous documents reflect the importance of buy-in from Kastner, Greytak, Bertschinger, Redwine (Dean for Undergraduate Education) who made the decision to pursue the initiatives.	• CNA – 18, 37, 67 • IKA – 33 • INA – 14 • IR – 27 • JA – 17 • PIT – 21, 22, 23

Departmental and campus structures in place to support female students and faculty.	• One document lists several supportive policies (e.g., paid maternity leave for graduate students and faculty, access to quality childcare, automatic one-year delays in faculty tenure clock for childbirth, mentoring for faculty supervisors, department leaders, and students)	• IIW – 89
Incentives for faculty to teach in the TEAL format.	• Several documents detailed the incentives for teaching in the TEAL format (e.g., ready-made curriculum and materials, course load reductions, designing the course to be fun to teach, well-developed training, etc.)	• IIW – 61 • IR – 27 • PIT – 21
Strategy 3: Collaborative Leadership at Multiple Levels		
Finding	Examples	Reference Documents
Collaboration with faculty in the department to make initiatives happen.	• Several documents detail collaborations with faculty for TEAL course.	• IIW – 59, 60 • JA – 17, 25 • PIT – 21, 22
Collaboration with faculty and staff from other departments.	• Interview provides details about collaboration with faculty for flexible major option. • Interview reveals that several faculty in physics collaborate with OME on specific initiatives (e.g., Seminar XL, advisory committee, student programming, etc.)	• PIT – 22 • PIT – 23
Collaboration with faculty at other institutions	• Two documents noted that other institutions are replicating the SCALE-Up and TEAL models. • One document mentioned that Belcher collaborated with Beichner as part of a grant.	• INA – 4 • JA – 96 • INA – 8
Collaboration with students on recruitment initiatives	• One documents indicated that department leadership solicited help of students.	• CR – 40
Strategy 4: Flexible Vision		
Finding	Examples	Reference Documents
Revised SCALE-UP model to be more responsive to the MIT context.	• Report mentioned need adjusting aspects of SCALE-UP model to be more suitable at MIT.	• CR – 6

Refinements to the TEAL format were made as a result of evaluation.	• Several documents listed changes (e.g., ensuring heterogeneous mix of students in groups, more training for faculty teaching in TEAL, more staff to teach TEAL, fewer experiments in class, better course planning)	• CNA – 18 • INA – 9 • JA – 17 • PIT – 21
Strategy 5: Professional Development		
Finding	Examples	Reference Documents
Additional faculty training was needed when going from pilot to full implementation of TEAL format.	• Several documents mentioned that new instructors for first large TEAL class were not adequately prepared.	• CNA – 7 • JA – 17 • PIT – 21
Students needed more training about the purpose for and the processes involved with learning in groups.	• A few documents mentioned that students did not understand how to work productively in groups.	• CNA – 7 • INA – 9 • IR – 27 • JA – 17
Faculty received better training in subsequent years.	• Two documents indicated that this was the case.	• INA – 8 • IR – 27
Strategy 6: Planned Attention to the Environment for Women and URMs		
Finding	Examples	Reference Documents
Group-based belief system that is inspiring, strengths-based, and focused on connectedness to the communities from which students come	• Student mentioned working in groups to solve problems (e.g., study groups, class work groups, etc.). • A few documents described TEAL student groups designed to have students with strong physics backgrounds to assist students with weaker physics backgrounds. • Two documents mentioned the promotion of excellence.	• ECRS – 3 • NA – 90 • CNA – 7 • JA – 17 • PIT – 21 • CR – 31 • INA – 86
Pervasive, highly accessible and multifunctional role structure in which students vacillate between learners and mentors in multiple settings that complement the academic program	• Three documents mention students who later become TA's, tutors, etc. in TEAL classes and OME programs.	• ECRS – 3 • INA – 4 • PIT – 23
A multi-faceted, peer-based support system that addresses the holistic needs of the students and that provides a sense of community	• Setting was considered important aspect of TEAL format – conducive to learning. • OME staff provide programs that focus on psychological needs of students (e.g., critical mass, imposter syndrome, etc.)	• IW – 5 • PIT – 21 • CNA – 30 • PIT – 23

Empowering program leadership that is shared, inspirational, highly skilled, and committed to the students	• Several documents mentioned student-faculty engagement as being important aspect of TEAL initiative. • Several documents also mentioned how supportive faculty in the physics are of their students. • Numerous documents mention the skill of the faculty involved with TEAL.	• INA – 4 • JA – 17, 25 • PIT – 21 • CB – 32 • CNA – 12, 69, 97 • INA – 4 • JA – 17 • PIT – 21, 22, 23 • INA – 4 • JA – 17 • NA – 90 • PIT – 24
Flexible major gives students opportunity to make meaningful choices, which is consistent with literature.	• Students mentioned choosing the physics major because of the flexible option and being able to combine the career with another discipline in service to others.	• CB – 32 • CNA – 30 • DIW – 65 • ECRS – 3
Strategy 7: High impact visible actions staged over time		
Finding	Examples	Reference Documents
Incorporated flexible major option in physics.	• Numerous documents reference flexible major option when discussing increase in women in the physics department.	• CB – 32 • CR – 13 • DIW – 65, 66 • ECRS – 24 • IKA – 33 • INA – 14 • PIT – 22
Renovated studio physics reading room for TEAL format	• Several documents referenced the creation of state-of-the-art classroom space	• IKA - 34 • IR – 27 • JA – 17, 25
Conducted two pilot studies of TEAL format.	• Several reports, journal articles, and articles provided specifics about the pilot study.	• CNA – 7, 18 • CR – 6 • INA – 8 • IR – 27 • JA – 25 • PIT – 21
Transformed introductory physics with TEAL format, which combines lecture, recitation, and labs for an active learning approach.	• Several documents mention this combination and its usefulness to student engagement	• CNA – 18 • FB – 92 • INA – 4, 10, 35 • JA – 17, 25 • NA – 90
Technology in the introductory course helped with helping students grasp complex concepts.	• Several reports and journal articles provided examples of how the visuals were helpful when teaching electromagnetism.	• CR – 6 • IIW – 60 • INA – 9 • JA – 25, 26 • PIT – 21

Conducted several diversity-related departmental reviews.	• A couple of documents referenced the Title IX review in which the physics department was commended for its efforts to increase participation of women. • Affirmative action review of faculty and student recruitment was mentioned in one document.	• CNA – 11 • IKA – 33 • CNA – 11
Encouraged student participation in academic services provided by Office of Minority Education (OME).	• Documents reveal that the department leadership supported efforts of OME (e.g., Seminar XL, tutorial programs, etc.)	• IIW – 72, 83 • IKA – 33 • PIT – 22, 23
Physics department engaged in efforts to recruit women and URMs as faculty.	• Two documents referenced MIT Pappalardo Fellowships in physics.	• CR – 54 • INA – 98
Strategy 8: Continuous assessment and evaluation		
Finding	Examples	Reference Documents
Track participation rates for flexible majors.	• One participant and one college report detailed the information collected on participation in flexible major and how those majors are utilized	• CR – 31 • PIT – 22
TEAL students made gains nearly double those of their counterparts in the traditional course.	• Numerous documents referenced these gains – some in more detail than others, but all with a similar message.	• CNA – 7 • INA – 4 • JA – 17, 25 • NA – 87 • PIT – 21
Assessment and evaluation for TEAL courses was a high priority.	• Numerous documents mentioned the skill of Dori in conducting comprehensive assessments (e.g., 2 experimental groups and control group, types of instruments used for assessment, quantitative and qualitative analysis) • One participant talked about the informal assessment (e.g., TEAL instructor has gut sense of what students are learning, reading comments from satisfaction surveys)	• CNA – 7 • CR – 6 • IIW – 59 • INA – 8, 9, 10 • IR – 27 • JA – 17, 25, 26 • PIT – 21 • PIT – 22
Assessment was a strategy for overcoming barriers.	• Several documents mentioned that TEAL would not have been successful without having had data to show its effectiveness.	• INA – 8 • JA – 17 • PIT – 21

Monitor success of students participating in OME initiatives	• One participant detailed the extent to which these are monitored	• PIT – 22
Other Strategies		
Admissions played a role in success with enrolling students.	• One participant and several documents referenced the role that admissions played in providing a diverse student body. • Two blogs since 2000 indicate that diversity was a priority for admissions.	• CNA – 30 • CR – 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53 • IIW – 57, 58, 71 • PIT – 22 • IB – 1, 100
The culture of the department played a role in creating a supportive environment	• An article referenced initiatives to increase interactions with industry. • Documents described the overall climate in the department as welcoming and supportive of students. • One document mentioned that historically the physics department had championed innovative teaching practices.	• INA – 2 • CR – 64 • PIT – 21, 22, 23 • CR – 29
Common core potentially played a role in the success of initiatives.	• Several documents referenced the common core and its importance (e.g., exposure to various disciplines)	• CB – 28, 32 • ECRS – 3 • NA – 36 • PIT – 21, 23
Funding played an integral role in the success of the TEAL initiative.	• Numerous documents highlight contributions from D'Arbeloff ($10 million) & Microsoft ($25 million). • Two documents reference $1.5 million TEAL classroom. • One document referenced the staffing that was hired or utilized because of the available funding.	• CNA – 15, 18, 37, 91 • IIW – 59, 60 • INA – 8 • IR – 27 • JA – 17 • NA – 87, 90 • PIT – 21 • JA – 17 • IIW – 59 • PIT – 21

Campus culture of dealing with tension around issues of inclusion and excellence.	• Several documents mentioned tension around stereotype that inclusion will lead to less qualified faculty and students. • Several campus programs to address these issues (e.g. Human diversity and social order forum series, annual conference on diversity, office of minority education, etc.) • One participant mentioned the fifth-flag system, which early warning system to catch students who have less than a "C" average after the fifth week.	• CB – 88 • CNA – 12, 68, 93, 94, 101 • CR – 41 • IIW – 89 • CNA – 12 • CR – 13, 41 • IIW – 55, 56, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 102 • PIT – 23
Leadership associated with initiatives highly motivated around diversity issues.	• Several documents give examples of leaders personally experiences and motivations for championing inclusive excellence. • Several documents also describe the extensive amount of time that went into researching and planning for the TEAL initiative.	• CR – 13 • INA – 14 • JA – 17 • NA – 90 • PIT – 21, 22, 23 • PIT – 21
Champions of initiatives were highly skilled.	• Many documents speak of the expertise of the faculty, administration, and staff associated with the initiatives.	• CR – 13 • IB – 1 • IIW – 59 • INA – 4 • IR – 27 • JA – 17 • NA – 90
Several initiatives were geared to quality instruction for all students, and this emphasis attributed to increase in women and URMs.	• One document mentions that the flexible major option and the TEAL format were geared toward all students.	• PIT – 22
Barriers		
Not all faculty felt TEAL was an appropriate approach for teaching.	• Several articles referenced lack of consensus among faculty about lecture vs. TEAL format (e.g., Walter Lewin).	• CB – 28 • CNA – 19, 37 • CR – 6 • DIW – 63 • INA – 8 • IR – 27 • JA – 17, 25 • PB – 95 • PIT – 21, 22

Stereotype that inclusion means lowering quality	• One document references implicit and sometimes explicit bias against women and URMs by faculty members.	• CR – 13
Campus in general had difficulties with hiring URMs as faculty.	• One news article referenced the lack of URMs as faculty.	• CNA – 16
Students protested the change to TEAL format.	• Several documents mention student dissatisfaction with the new course because they wanted lecture-style teaching and because they did not like the attendance requirement.	• CB – 28 • CNA - 37 • JA – 17 • IR – 27 • PB – 95 • PIT – 21
Some students' perceptions of the flexible major option are not well-informed.	• One document details conversations about double majoring in physics and the discussions don't align with the option as it is detailed in documents about the flexible major.	• ECRS – 24
Difficulty finding space for TEAL classroom.	• One document mentioned Kastner felt finding space was a major obstacle. • Documents mentioned students' opposition to having the classroom on the top floor of the student center, a popular study area.	• CNA – 34 • IR – 27

APPENDIX E: SUMMARY OF FINDINGS

UT Austin – Cockrell School of Engineering

Document Type	*Abbreviation*	*# of Document*
College Information on Website	CIW	18
College News Article	CNA	5
Conference Paper	CP	3
College Report	CR	8
External College Review Site	ECRS	1
External Organization Website	EOW	2
External Report	ER	1
Grant Information	GI	1
Industry Report	IR	1
LinkedIn	LI	1
News Article	NA	5
Participant Interview Transcript	PIT	2
State Government Website	SGW	4
University Dissertation	UD	1
University Information on Website	UIW	5
University Minutes	UM	2
University News Article	UNA	7
University Report	UR	6
TOTAL		73

Strategy 1: Clear understanding and articulation of the rationale for change		
Finding	Examples	Reference Documents
General FIGs designed to improve first-year experience for women and URMs	• Two documents provides details about the general rationale for all students.	• UD – 1 • UTA – 22
EOE FIGS designed to increase retention rate of first-year minority students in Cockrell School of Engineering (CSE).	• Three documents mention the purpose of the EOE FIGs.	• CP – 17, 18 • ER - 4
There was a gap in retention rates between minority and non-minority in CSE.	• Three documents mention this gap.	• CP – 17, 18 • ER – 4
There was a large percentage of African American, Hispanic, and Native American students with limited exposure to strategies and resources for academic success.	• This was indicated in several documents.	• CP – 17, 18 • ER – 4 • PIT – 7

Help students form study groups.	• Two documents noted the importance of establishing study groups.	• ER – 4 • PIT – 7
Help students with transition from high school to college.	• Two documents suggest that helping URMs with transition to college as goal.	• CIW – 62 • PIT – 7
Offer pipeline to high school students.	• One document details the programs offered for high-school students.	• PIT – 7
CSE faculty and WEP program administrators researched research models at UC Davis and other institutions to find a model from which to adapt their own model.	• Participant 8 detailed the implementation process, which included researching the model at UC Davis and other models.	• PIT – 8
Promote excellence in academics, leadership, professionalism, and community support.	• Three documents note this emphasis on academics, leadership, professionalism, and community support in both EOE and WEP programs.	• EOW – 10 • PIT – 7, 8
Workplace diversity improves business' need to serve a broad customer base.	• One document highlighted how classroom diversity prepares students for workplace diversity.	• CIW – 55
Strategy 2: Buy-In and Advocacy from Senior Leadership		
Finding	Examples	Reference Documents
Incentives were offered for student participants	• Two documents reference the mentor stipends.	• UD – 1 • UNA – 2
First female dean appointed in 2014.	• One article references the interim dean Sharon Wood.	• UNA – 3
Dean and leadership team make final decisions about which programs to pursue	• A faculty participant mentioned that the dean and the leadership team make decisions about where to make investments in programs..	• PIT – 7
Even though EOE and WEP are externally funded, there is a commitment to maintaining staffs of at least 4 in both program areas.	• Two participants mentioned the staffing in the EOE and WEP programs.	• PIT – 7, 8
Strategy 3: Collaborative Leadership at Multiple Levels		
Finding	Examples	Reference Documents
FIGS require collaborative efforts between faculty, students, advisors and EOE/WEP program staff of numerous departments.	• Three documents reference the collaborations that were necessary during the implementation process. • Three documents reference the collaboration necessary currently.	• CP – 17, 18 • UD – 1 • CP – 17, 18 • UD – 1

CSE partners with numerous industries with programs designed to recruit students.	• One document referenced the State of the Cockrell School address in 2008, which specifically referred to industry collaborations (e.g., more than 500 volunteered with EOE and WEP initiatives)	• UR – 31
Strategy 4: Flexible Vision		
Finding	Examples	Reference Documents
Results of assessment utilized to revise aspects of the program.	• Several documents referenced changes that have been made based on assessment (e.g., selecting more qualified advisors, changing from social to academic focus, moving from 1-semester to 2-semester offerings, curriculum sequencing, etc.).	• CP – 18 • PIT – 7, 8 • UD – 1
	•	•
Strategy 5: Professional Development		
Finding	Examples	Reference Documents
FIGs provide training for students	• Two documents indicate that student mentors must undergo over 40 hours of training. • Several documents mention rigorous mentor selection process	• UD – 1 • UR – 22 • UD – 1
FIGs provide training for professional advisors and faculty.	• One document indicates that in the beginning professional advisors and faculty attend training sessions in the summer, although they are not required.	• UD – 1
New staff in WEP learn fundraising techniques by shadowing more seasoned staff.	• One participant described how fundraising training occurs – basically learning by doing.	• PIT – 8
Strategy 6: Planned attention to the environment for women and URMs		
Finding	Examples	Reference Documents

Group-based belief system that is inspiring, strengths-based, and focused on connectedness to the communities from which students come	• Students have opportunities to participate in over 90 student organizations within the CSE, not including all the other organizations offered at the University. This is referenced as allowing students to find a place to fit in based on their interests, while also helping them develop leadership skills. • Names of programs indicate commitment to positive or strengths-based messages (e.g., The Achievers for Electrical & Computer, The Visionaries for Mechanical, Infinite Momentum A for Interdisciplinary, Strength in Numbers for Aerospace & Civil, The Innovators for Interdsiciplinary, and Infinite Momentum B for Electrical & Computer)	• CIW – 54, 62 • PIT – 7 • UIW – 37 • UR – 31 • CP – 17, 18
Pervasive, highly accessible and multifunctional role structure in which students vacillate between learners and mentors in multiple settings that complement the academic program	• Mentors take the same classes as students in the FIGs will take, which is mentioned in one document. • Several documents note the structure of the EOE and WEP FIGs, which includes professional staff and student staff.	• PIT – 7 • CP – 17, 18 • PIT – 7, 8

A multi-faceted, peer-based support system that addresses the holistic needs of the students and that provides a sense of community	• Several documents mention the goal of the EOE FIG program, which is to develop a community of learners who feel connected to their peers, faculty, and staff • Two documents also mention how the EOE programs address psychological issues that URMs face (e.g., culture shock, isolation, lack of confidence, stereotype threat, etc.) • All programs are designed to offer flexible options, as was mentioned in numerous documents. • One article references the framing of STEM as areas that work to make the world a better place, which is more appealing to women.	• CP – 17, 18 • ECRS – 20 • ER – 4 • PIT – 7, 8 • PIT – 7, 8 • PIT – 7 • UNA – 34
Empowering program leadership that is shared, inspirational, highly skilled, and committed to the students		
Many programs focused on academic excellence.	• One document details the emphasis on mastering skills necessary to achieve in courses.	• PIT – 7
Strategy 7: High impact visible actions staged over time.		
Finding	Examples	Reference Documents
WEP FIGS piloted in 1998 in the University FIG program.	• Documents provide details about the pilot programs.	• UD – 1 • UR – 22
EOE piloted two FIG courses in fall 2000 and then doubled the number offered in 2003.	• One document detailed the implementation process for the EOE FIGs.	• CP – 17, 18
EOE FIGs are offered in the fall and spring semesters and are major-based.	• Several documents detail the EOE FIG four course offerings: mechanical engineering; electrical engineering; aerospace, architectural, and civil engineering; and petroleum, biomedical, and chemical engineering.	• CIW – 53, 58, 62 • CP – 17, 18 • ER – 4 • PIT – 7
WEP FIGs are offered in the fall and spring semesters and are major-based.	• One document mentions the WEP FIGs as being instrumental to retention of female students.	• PIT – 8

WEP First-Year initiative program is a mentoring program for first-year female students.	• One document references the mentoring program (list the specific program name here.)	• PIT – 8
GLUE program piloted in in 2001.	• Participant 8 discussed the implementation process.	• PIT – 8
WEP Undergrad research program, GLUE, is another strategy that helps with retention of women. This program was started in 2001 and was initiated by a faculty member.	• One document references the research opportunities through Graduates Linked with Undergraduates in Engineering (GLUE).	• PIT – 8
WEP is piloting another research group in Fall 2014.	• Participant 8 mentioned piloting a new research group in the fall to see if it's feasible to run it in the fall and spring semesters.	• PIT – 8
Aggressive marketing of FIGs	• Several documents describe the aggressive marketing of the program over the summer (e.g., course schedules, web page, departmental meetings, summer programs, etc.).	• CIW – 61, 62 • CP – 17, 18 • UD – 1 • UR – 22
Students participating in FIGs are registered in clusters.	• Two documents detail the registration process	• PIT – 7 • UD – 1
Class curriculum includes topics geared to first year students.	• Three documents describe the topics covered in the class (e.g., time management, study strategies, getting to know professors, campus traditions, career exploration, and campus tours.)	• CP – 17, 18 • UD – 1
EOE programs are offered as a way to increase retention and graduation rates of URMs.	• Numerous documents cite the programs of EOE as important to retention and graduation of URMs – specifically Hispanic, African American, Native American, and Native Hawaiian.	• CIW – 47, 50 • CNA – 49, 60 • CP – 17, 18 • CR – 59 • NA – 27 • PIT – 7 • UNA – 33
WEP programs are offered as a way to increase retention and graduation rates of women.	• Numerous documents cite the programs of WEP as important to the retention and graduation of women.	• CIW – 50, 63, 65, 68 • CNA – 46, 49 • UR – 22
Faculty experimenting with modified flipped classroom opportunities.	• One participant mentioned that faculty are experimenting with modified flipped classroom opportunities (e.g., online practice problems)	• PIT - 7
Faculty offer general engineering sections for engineering mechanics courses.	• A faculty participant mentioned the general engineering sections for engineering mechanics courses.	• PIT – 7

Faculty are now focusing on better instruction in first-year calculus courses, which is a course in which there is a high failure rate.	• One document mentions this initiative.	• GI – 14
Strategy 8: Continuous assessment and evaluation		
Finding	Examples	Reference Documents
Track the retention of students who participate in FIGs vs. those who do not.	• Several documents reveal that those who participate in FIGS are retained at higher percentages.	• CP – 17, 18 • ER – 4 • UD – 1 • UNA – 13 • UR – 22
Program administrators in EOE and WEP track academic progress of FIG participants.	• Three documents showed that students who participated in FIGs had higher GPAs in their technical courses than those who did not participate in FIGs.	• CP – 17, 18 • UR – 22
Program administrators began tracking graduation rates in the latter years.	• One document describes the information collected on graduation rates.	• CP – 18
Students also complete satisfaction surveys	• Three documents mention these surveys and provide copies of specific instruments. These surveys indicated that students felt they received information that helped them transition into the rigors of CSE.	• CP – 17 • ER – 4 • UD – 1
During the early years, recognized that more qualitative analysis was needed.	• One document mentioned that more qualitative assessment was needed.	• UD – 1
Results of assessment utilized as recruitment tool.	• One participant (participant 3) mentioned that the outcomes of assessment are shared with students so that they recognize the benefit of participating in a FIG.	• PIT – 7

Other Strategies		
Texas higher education policies seem to be major influence in the enrollment of women and URMs.	• Three documents and one participant interview mentioned the Ten Percent rule, which guarantees that if students are in the top 10% of their class, they're eligible for automatic admission to any public university in Texas. • Participant 8 and other documents mentioned the Four-Year Graduation Plan as a major emphasis in CSE. • Two documents reference the Closing the Gaps initiative as having an impact on enrollment of women and URMs. • One document notes the affirmative action policies that are a major issues at UT Austin, especially in light of the Fisher v. UT Austin case argued in the Supreme Court. • One of the documents referenced Governor Perry's Higher Education Initiative in the early 2000s. • UT System has specific goals for engineering across the system and many of these relate to diversity, as is discussed in one document	• ER – 5 • SGW – 6, 21 • CP – 15, 17 • PIT – 8 • UIW – 36 • UM – 28 • UR – 12, 38 • SGW – 24, 25 • NA – 12 • UM – 29 • UR – 72
Started out paying peer mentors in FIGs, but funding ended for that.	• Participant 8 mentioned that funding ended for paying mentors, but that did not affect the number of students who participated as mentors.	• PIT – 8
Funding of EOE and WEP programs is important aspect of program's success.	• All participants and numerous documents indicate that the EOE is funded externally.	• CIW – 56, 57, 61, 64, 66 • CNA – 40, 48 • CP – 18 • CR – 44 • IR – 11 • NA – 26 • PIT – 7 • UIW – 70 • UNA – 13, 32 • UR – 22

EOE and WEP program leaders are passionate about the programs in their areas and are engineering graduates themselves.	• Several documents mention the educational backgrounds of the EOE and WEP directors. • Several documents also mention the passion the staff have for the work that they do.	• CIW – 67, 71 • CP – 18 • PIT – 7, 8 • UR – 31 • UTA – 35
University and CSE culture of innovation and higher education reform.	• Two documents mentioned a specific focus on curricular reform. • Another document focuses on academic excellence through initiatives in the Division of Diversity and Community Engagement.	• UR – 30, 31 • UIW – 69
Enrollment in engineering is increasing across the country, which has affected enrollment at UT Austin.	• Two documents reference the national enrollment trends for women in engineering and the sciences.	• NA – 73 • UNA – 34
Barriers		
At the start of EOE FIGs, not all staff were familiar enough with the engineering curriculum	• One participant (participant 4) mentioned that administrative assistants were utilized as advisors, but they weren't as effective because they did not know the curriculum.	• PIT – 07
Because EOE and WEP are externally funded, funding is as much of a challenge as it is an opportunity.	• One participant (participant 4) mentioned funding as a barrier. • One participant (participant 5) mentioned funding as a mixed blessing and noted the challenging aspects of having to raise funds for everything – even staff and equipment.	• PIT – 7 • PIT – 8
Challenge of transitioning new EOE staff.	• One participant (participant 5) mentioned the challenge of helping new EOE staff understand the culture of CSE.	• PIT – 7
Ten percent plan reduced to 7 percent at UT Austin.	• One article described the impact of moving from 10 percent to 7 percent, which writer speculated would decrease Latino admit rate.	• NA – 19
College still struggles with graduating African Americans.	• One article discusses the difficulties with enrolling African Americans.	• NA – 27
Challenge of getting faculty engaged more with students.	• One article and one participant made mention of wanting faculty to be even more engaged.	• CNA – 40

APPENDIX F: SUMMARY OF FINDINGS

Cross-Case Analysis

Strategy 1: Clear understanding and articulation of the rationale for change			
Finding	HMC Example	MIT Example	UTA Example
Thorough research on external trends.	• 16 documents referenced the research that the CS faculty had done to understand why girls/women were not attracted to CS.	• 1 document referenced trends in physics enrollment at Harvard as impetus for flexible major option • 8 documents referenced research on SCALE-Up model at NCSU and other places.	• 1 document referenced research models at UC Davis and other institutions. • 2 documents referenced the research conducted on FIG models at other institutions.
Thorough research on internal trends	• 3 documents referenced attention to enrollment trends in CS courses.	• 1 document addressed enrollment in physics and lack of flexibility in major offerings. • 9 documents referenced lack of physics learning lab. • 10 documents referenced lack of student engagement in physics intro courses. • 13 documents referenced failure rates in physics • 8 documents referenced either SCALE-Up model or constructivist theory.	• 3 documents referenced gap in retention rates of women/minorities and white males. • 4 documents referenced the limited exposure to strategies and resources for academic success among women and URMs.
Strategy 2: Buy-In and advocacy from senior leadership			
Finding	HMC Example	MIT Example	UTA Example
Buy-in from senior leadership	• 20 documents referenced support and advocacy of college president. • 4 documents referenced support from faculty chair.	• 10 documents referenced support of department heads and dean of undergraduate education (1 document)	

Faculty incentives for supporting initiatives	• 4 documents referenced tenure and promotion guidelines as being supportive of HMC initiatives.	• 3 documents referenced incentives for teaching in the TEAL format.	
External support for initiatives.	• 3 documents referenced external support from industry leaders, such as Sandberg and Eustace.		• 15 documents referenced the policies that were supportive of initiatives such as those in EOE and WEP.
Strategy 3: Collaborative leadership at multiple levels			
Finding	HMC Example	MIT Example	UTA Example
Interdisciplinary collaboration	• 4 documents referenced collaboration with biology department.	• 1 document referenced collaboration necessary for flexible major.	• 1 document mentioned collaboration with engineering and math faculty because of the high failure rates of engineering majors in calculus courses.
Collaboration across departments/school/ university	• 7 documents referenced collaboration between CS and other departments (e.g., admissions, advancement, president's office, etc.)	• 1 document referenced collaboration with OME.	• 3 documents referenced collaborations with numerous departments across the institution for FIGs.
Collaborations with external organizations	• 7 documents referenced collaboration with K-12 institutions and other Higher Ed institutions for developing programs at those institutions.	• 2 documents mentioned collaborations with faculty at other institutions to replicate TEAL • 1 document mentioned collaboration with Beichner from SCALE Up model during implementation phase.	• 1 document referenced collaborations with industry leaders, 500 of which volunteered with EOE and WEP initiatives.
Strategy 4: Flexible vision			
Finding	HMC Example	MIT Example	UTA Example
Revisions based on assessment and evaluation	• 3 documents referenced making revisions based on assessment and evaluation.	• 4 documents referenced changes made to TEAL based on results of pilot programs.	• 4 documents reference changes to FIGs based on assessment and evaluation.

Strategy 5: Professional development			
Finding	HMC Example	MIT Example	UTA Example
Faculty training to support initiatives	• 1 document referenced the research process serving as training for faculty in CS.	• 5 documents referenced faculty training for TEAL (both for technology and for curriculum.)	• 1 document indicates that there are faculty training workshops for FIGs, although they are not mandatory.
Strategy 6: Planned attention to the environment for women and URMs			
Finding	HMC Example	MIT Example	UTA Example
Group work was key to student engagement and learning.	• 2 documents mentioned how group work contributed to learning in the introductory CS course.	• 7 documents referenced the importance of group work to learning in the TEAL course.	• 2 documents describe various activities that involve group work.
Students' roles vary between being learners and teachers.	• 2 documents referenced how groups were developed to include experienced and inexperienced student programmers.	• 3 documents referenced how groups were developed to include students from strong and weak backgrounds in physics.	• 5 documents referenced interactions between new students and peer mentors.
Programs foster a sense of community.	• 1 document referenced the community that was formed among GHC conference participants.	• 1 document referenced the sense of community that was formed in TEAL classes.	• 6 documents reference the sense of community that is fostered through EOE and WEP programs.
Programs address psychological issues students face.	• 5 documents focused on the attention to helping students cope with psychological issues that arise from being women in CS.	• 2 documents mention OME's focus assisting students with psychological issues associated with being from underrepresented groups.	• 2 documents addressed how EOE and WEP provide support to students based on a number of psychological issues that arise from being from underrepresented groups.
Programs focus on confidence that comes from mastering course content.	• 2 documents focus on attention to mastering challenging course work and feeling good about being problem-solvers.	• 2 documents mentioned the importance of making sure that underrepresented students were focused on excellence.	• 1 document focused on teaching students the skills necessary to master the rigorous course load in engineering.
Strategy 7: Visible action that is staged over time			
Finding	HMC Example	MIT Example	UTA Example

Most initiatives were highly visible.	• Just about all the documents focused on three initiatives – intro course options, GHC conference participation, and freshman research.	• Most documents focused on four initiatives/programs and emphases – flexible major, TEAL, EOE programs, and departmental programs fostering welcoming environment.	• Most documents focused on EOE/ WEP FIG programs and EOE/ WEP programs.
Most major initiatives were piloted before full implementation.	• 29 documents referred to the staging involved with the major initiatives.	• 7 documents referenced the two pilot studies conducted for TEAL.	• 2 documents discussed the pilot program for WEP FIGs, which occurred in 1998. • 2 documents discussed the pilot program for EOE FIGs, which occurred in 2000.
Strategy 8: Continuous assessment and evaluation			
Finding	HMC Example	MIT Example	UTA Example
Assessment and evaluation was prioritized for every initiative, although some evaluation was more comprehensive than others.	• 10 documents referenced comprehensive assessment and evaluation of the three initiatives.	• 13 documents discussed comprehensive assessment of TEAL initiative. • 2 documents mentioned tracking participation in flexible major. • 1 document mentioned the various types of information collected for OME academic initiatives.	• 16 documents discussed comprehensive assessment of the EOE and WEP FIG initiatives.
Other strategies			
Finding	HMC Example	MIT Example	UTA Example
There was a focus on facilitating learning for all students.	• 2 documents mentioned faculty's overarching goal of improving instruction for all students.	• 1 document mentioned that the goals of the flexible major and TEAL format were geared to all students.	
Campus cultures were supportive of diversity efforts.	• 4 documents referenced the supportive environment of the campus community.	• 27 documents referenced the supportive environment of the campus community.	• 7 documents focused on campus initiatives related to increasing diversity at UT Austin.

Funding played a role in the success of all the initiatives, although the extent to which it played a role varied.	• 18 documents referenced the role that funding played in the success of the three major initiatives.	• 12 documents referenced the role that funding played in the success of the TEAL initiative.	• 16 documents referenced the role that external funding played in the success of EOE and WEP programs.
Leaders associated with initiatives were highly skilled and competent in their respective disciplines.	• 9 documents noted the skill and competence of faculty in the CS department who developed initiatives.	• 7 documents noted the skill and competence of faculty, administration and staff associated with initiatives.	• 7 documents noted the skill and competence of faculty and administrators associated with initiatives.
Admissions staff and policies played a role in the success of enrolling women and/or URMs.	• 1 document mentioned the role that the admissions staff played in the success of enrolling women at the college.	• 19 documents mentioned the role that the admissions staff and policies played in the success of enrolling women at the college.	• 14 documents mentioned the state and institutional policies guiding admissions at UT Austin.
Common core gave more students exposure to discipline.	• 7 documents refer to the common core that requires all students enrolled at HMC to take intro CS courses.	• 5 documents refer to the general interest requirements (GIR) or common core that requires all students at MIT to take physics.	• 1 document referenced the "signature courses" that exposed students to a variety of disciplines.
Department was already known for being open to innovation.	• 2 documents referred to the culture of the department as a factor in the success of the 3 major initiatives.	• 6 documents referred to the climate in the departments as being supportive of teaching innovations.	• 2 documents referenced culture of innovation in the department.
Barriers			
Finding	HMC Example	MIT Example	UTA Example
Stereotype that increasing diversity lowers quality	• 1 document referred to remnants of people assuming that standards must have been lowered for there to be so many women graduates in CS.	• 1 document referenced implicit and explicit bias against women and URMs based on the perception that they were not as capable.	
Challenge recruiting African Americans into major	• 1 document referenced difficulty of attracting African Americans to CS.	•	• 1 document referenced difficulty in enrolling African Americans into engineering majors.