Project Summary

Synthesis and Diffusion of Knowledge
Linking Self-Concept, Education, and Student Participation in STEM

The demand for STEM professionals continues to rise while the supply of adequately prepared students entering STEM fields declines. This has resulted in a dearth of personnel in the STEM workforce, particularly among women and other underrepresented groups. We (faculty in Social Psychology, Human-Computer Interaction and Computer Science) are interested in helping to reverse this trend. To accomplish this, we are submitting a proposal for a Knowledge Diffusion project where we will synthesize research from social psychology, education, and vocational studies related to student participation in STEM fields of study. This project will consist of an: 1) examination of the application of social psychological, educational, and vocational theories to STEM participation, 2) integration and comparison of current knowledge on best teaching practices across STEM-related disciplines, 3) the synthesis of 1 & 2 to examine how these two bodies of knowledge can be integrated to increase student participation and retention in STEM and 4) the diffusion of the results of this synthesis to STEM educators.

The Intellectual Merits of the synthesis proposed here lie in the integration of knowledge from disparate disciplines as they relate to STEM education. Currently, theorists and researchers from many areas are simultaneously attacking issues with direct application to increasing student participation in STEM in addition to ameliorating gender and racial disparities in STEM participation. However, there is little crosstalk occurring between these bodies of knowledge. This lack of synthesis can result in redundancy of efforts as well as (and possibly more importantly) the development of a body of knowledge that lacks the depth and complexity necessary to solve this very important and difficult problem. To fully understand the current lack of participation in STEM, it is necessary to understand how all aspects of the human experience contribute to an individual's decision to pursue an academic and professional career. The project proposed here will contribute to the intellectual body of work regarding participation in STEM by synthesizing bodies of knowledge regarding the educational, social and motivational elements of the human experience that my influence participation in STEM.

Broader Impacts: There is general consensus that the United States is experiencing a shortage of STEM professionals and graduate students pursuing STEM careers (e.g. U.S. Department of Commerce, 2005). The proposed project will attack this problem by synthesizing interdisciplinary knowledge and theory related to self-efficacy and personal values as they apply to STEM instruction. We submit that STEM faculty armed with this knowledge may be more successful in responding to individual student needs. This responsiveness could maximize students' participation and retention in STEM, and may also decrease existing gender and racial disparities. Thus, the knowledge gained from this synthesis will have broad impacts on: increasing the participation of underrepresented groups; improving overall retention in STEM; consolidating the understanding of social psychology, vocational and educational research findings on teaching and learning in formal and informal settings; and nationally disseminating this knowledge.

Project Description

Synthesis and Diffusion of Knowledge

Linking Self-Concept, Education, and Student Participation in STEM

Technological advances are integral to modern, industrialized societies and thus are an important part of economic and social development for most countries. Indeed, the technological advances of the last half of the 20th century and the first part of the 21st century are so pervasive and transformative that the workforce required to develop, apply, and utilize these advances has increased at an exponential rate. This increased demand for adults trained in mathematics and the sciences will continue to grow over the next century (Akbuluta & Looney, 2007). Unfortunately, although the need for people has grown, many modern countries and in particular the United States, have experienced decreasing numbers of students interested in many STEM disciplines, including engineering and computer science (Akbuluta & Looney, 2007; Board of Engineering Education, National Research Council, 1992). Given this circumstance, it is imperative that educators, scientists, and industry professionals find ways to increase student interest and participation in STEM related courses at all levels.

Ironically, our higher-education institutions have historically put little effort into training future STEM educators on how to instruct students. For example, although teachers in K-12 are required to complete some coursework in educational techniques, instructors at the college level do not necessarily have training in instruction. College professors have expertise in their area, but may not know how to best convey that knowledge to students not fully committed to the discipline. Thus, in order to increase the number of STEM professionals, colleges and universities not only have to recruit students to the field they must also use effective teaching methods to retain them.

Many STEM educators are aware of declining student participation, and are attempting to address this both through recruitment and specific instructional strategies (i.e., Hazari, Tai, & Sadler, 2007; Prince & Felder, 2006; Zang, 2007). However, they are not necessarily utilizing related knowledge from social psychology, education, and vocational studies. While specific instructional strategies may effectively transmit knowledge, they may not increase STEM participation. For example, group activities, use of PowerPoint, and simulations may be efficacious teaching strategies, but may not impact overall student participation and retention in STEM, as they do not address individual student characteristics impacting decisions to engage in the discipline (Gal & Ginsburg, 1994).

A number of professional organizations have discipline specific journals focusing on education, e.g., *American Biology Teacher*, the *Journal of Engineering Education*, and the *Journal of Statistics Education*. Although some of the material in these sources may relate to the specific discipline being examined, there is likely a great deal of overlap in effective teaching strategies across scientific disciplines. Furthermore, although research in these journals is informed by psychological, educational, and vocational models and research, there is currently no synthesis of these related bodies of work.

There are numerous psychological, educational, and vocational theories that directly or indirectly address motivational factors involved in academic and career choices, e.g., Bandura's Social Cognitive model of motivation (1997), Expectancy-Value Theory (Eccles & Wigfield, 2002), and Social Cognitive Career Theory (Lent, Brown, & Hackett, 1994). While these theories' explanations of academic and career choices are different, there are nevertheless many areas of overlap. For example, almost all of the theories identify self-efficacy and personal values as motivational factors.

The project we are proposing will synthesize these two bodies of knowledge—the current knowledge on efficacious teaching techniques in STEM and motivational factors associated with academic and career choices. In our synthesis we will:

- examine how many of the psychological, educational, and vocational theories identify self-efficacy (belief in personal competence) and personal values (such as altruistic goals) as influential motivating factors;

- explore how differences in defining these constructs might have practical implications for their application to instruction, and

- explore what types of personal values the theories identify, in particular looking for areas of overlap.

Eccles' Expectancy-Value Theory (Eccles & Wigfield, 2002) is an example of the kind of theory we will include in our synthesis as it 1) specifically addresses self-efficacy and personal values in making achievement-related choices, 2) is applicable to adult learners, 3) has specific application to academic and career decisions (for example, Eccles, Barber, & Jozefowicz, 1998), 4) addresses gender and racial disparities in STEM (for example Frome, Alfeld, Eccles, & Barber, 2006), and 5) has a large body of empirical evidence supporting its validity (for example Simpkins, Davis-Kean, & Eccles, 2006). Eccles and her colleagues propose that expectancies and personal values influence the likelihood of entering and persisting with a discipline (Eccles & Wigfield, 2002). Expectancies can be either task or discipline specific, and typically are identified by the answer to the question: "How likely I am to succeed at…?" There is a distinction between a broad belief in the chances for success within a domain and a more focused belief on the ability to succeed at a given task. Thus, a person may be confident that they could be successful in science, but doubt their ability to pass organic chemistry.

Similar to expectancies, values can also be specific to the domain. Eccles et al. (1983) identify 4 task-specific values: attainment value, intrinsic value, utility value, and cost. *Attainment value* is how much the individual values success at a task. This entails how much the task, or domain, taps into self-perception. People are more likely to engage in activities that, if they succeed, enhance their self-perceptions. Eccles and her colleagues define *intrinsic value* as the inherent pleasure in engaging in activities or studies related to the domain. People persist at activities people enjoy. *Utility value* is how well an activity fulfills an individual's short or long-term goals. Thus, someone may choose a career because it meets their long-term goal of a high salary, or fulfills their goal of helping others. Finally, Eccles (1987) proposes that *cost*, the negative aspects of an activity, is an important influence on achievement related choices. For example, someone may not enter a discipline because of perceived isolation. Indeed, this has been used as an explanation for why some underrepresented groups may not pursue STEM careers. For instance, Maton & Hrabowski (2004) contend that African-American students are less likely to persist in STEM fields of study because of academic and social isolation.

Numerous studies, using various theories, support Eccles' contention that self-concepts regarding an individual's ability and an individual's values predict that person's selection of academic courses, majors, and future careers (Eccles, 1987; Eccles, Barber & Jozefowisz, 1998; Frome, Alfeld, Eccles, & Barber, 2006; Simpkins, Davis-Kean & Eccles, 2006; VanLeuvan, 2004; Watt, 2006: Weisgram & Bigler, 2006; Weisgram & Bigler, 2007). Many of these studies also show gender and racial differences in self-concepts and values (Gainor & Lent, 1998; Fouad & Smith, 1996; Hackett, Betz, Casas & Rocha-Singh, 1992; VanLeuvan, 2004; Weisgram & Bigler, 2006) partially explaining gender and racial disparities in interest and participation in STEM related fields (NSF, 2003).

Self-efficacy, a belief in one's ability to succeed at a given task, appears to play a central role in students' selection of courses, choice of major, and eventual career paths (Eccles & Wigfield, 2002; Lent, Brown & Hackett, 1994; Navarro, Flores & Worthington, 2007). Students who believe they have higher abilities in an area are more likely to choose to take related courses. One area that crosses all STEM related fields is mathematics. In fact, students who have lower math self-efficacy are less likely to choose STEM related fields of study (VanLeuvan, 2004). The link between self-efficacy and entering STEM is particularly important for underrepresented groups, i.e. women, African-Americans, Native Americans, and Latino/as, since they 1) tend to have lower self-efficacy for STEM (Gainor & Lent, 1998; Fouad & Smith, 1996; Hackett, Betz, Casas & Rocha-Singh, 1992; VanLeuvan, 2004; Weisgram & Bigler, 2006), and 2) are less likely to choose STEM even with moderate levels of self-efficacy (Watt, 2006). For instance, Weisgram and Bigler (2006) found that self-efficacy was positively related to middle-school girls', but not boys', interest in science. They suggest this may be due in part to science being considered traditionally masculine, so that females entering STEM disciplines must be particularly confident. Thus, targeted efforts to increase student self-efficacy in mathematics, physics, computing, and engineering might have particularly dramatic effects on underrepresented student populations. One of the key ways to improve self-efficacy is providing opportunities for performance accomplishment (Crippen, & Earl, 2007; Johnson, & Liber, 2008; Luzzo et al, 1999).

While important, self-efficacy alone does not predict engagement in STEM (Frome, Alfeld, Eccles & Barber, 2006), thus "just because I can, does not mean I want to" (Weisgram & Bigler, 2006). Personal values also influence choice of academic coursework and potential careers (Eccles & Wigfield, 2002). Personal values include interests, money, altruism, and need for social contact (Weisgram & Bigler, 2006), all of which have been linked to likelihood of pursuing STEM careers. The intrinsic value an individual attaches to a discipline relates to course selection and career path (Wigfield & Eccles, 1992; Watt, 2006). Specifically, students who enjoy carrying out tasks related to the specific STEM discipline will be more likely to take courses in that area. Utility is another discipline specific characteristic that influences achievement-related choices (Eccles & Wigfield, 2002). While utility in general predicts pursuit of STEM related academic coursework, similar to evidence on self-efficacy, the effect is different for males and females. Males who attach moderate to high utility to STEM are likely to pursue it, as are females who report high-utility for science; however, females that believe science is only of moderate-utility are no more likely to engage in STEM than those who give it low-utility (Watt, 2006).

Other more personal values also influence the choice of academic path. For instance, women are more likely to value altruistic pursuits and are less likely to choose careers they perceive as "not helping others" (Eccles, 2007). However, increasing their perception of science as an altruistic pursuit increases their interest in science as a potential career (Weisgram & Bigler, 2006). Similarly, African-Americans and Latino/as may weigh income potential of careers more heavily then European-Americans (Weisgram & Bigler, 2006). Thus emphasizing possible higher salaries of STEM careers could increase the likelihood of African-American and Latino students pursuing related academic majors.

There are numerous existing studies and programs designed to increase participation in STEM, particularly in underrepresented groups. For example, Johnson, Kahle & Fargo (2006) examined the relationship between teaching effectiveness and student achievement in science. Effective teaching increased overall student achievement in science and reduced racial differences in achievement. They identified best teaching practices including problem based, active learning and flexible adaptation to individual student needs. Research by Weisgram & Bigler (2006) provides an example of one way to adapt to individual student needs. They found that an intervention increased females' belief in the altruistic value in science and that the more they believed that science was altruistic, the higher their self-efficacy for science, and the more interest in pursuing a STEM plan of study. For individuals with a high personal need for altruism, emphasizing the altruistic elements of science is likely to be beneficial. Although both of these studies focus on K-12, intuitively the findings seem applicable to adult learners as well.

The NSF funded Meyerhoff Scholars Program seeks to increase African-American participation in STEM by emphasizing factors that contribute to success in the sciences (Matson & Hrabowski, 2004). This successful program strengthens STEM participation by increasing faculty-student contact and mentoring, peer support through study groups and hands on research. These techniques are likely to improve student retention in all populations, but may be particularly beneficial for underrepresented groups by decreasing their feelings of isolation (Matson & Hrabowski, 2004).

Overall these studies indicate that a student's self-concept, specifically self-efficacy and personal values, influence the likelihood they will enter and complete STEM fields of study. If STEM programs are going to experience an in increase the number of students entering and graduating from their programs, they must at some level address these individual concerns. This may work not only to increase overall student participation in

STEM, but may also serve to ameliorate some of the gender and racial imbalances. Although there is a great deal of information on factors that may lead to student interest in STEM and ways to increase STEM participation, this information is spread out across a variety of disciplines. Moreover, this information is often not distributed to those who need it the most, faculty teaching STEM courses. To date, there is no single source systematically examining the interactions between students' self-concept and efficacious teaching strategies. Through such an examination, the knowledge base of these two broad areas of study can be synthesized in a manner that will not only allow for a greater understanding of how and why people choose STEM academic and professional careers, but will also facilitate the clear communication of this knowledge to those who need it—the faculty.

Our research team consists of university faculty in psychology (Social Psychology and Human-Computer Interaction) and computer science, and we are interested in increasing the number of students who pursue graduate degrees in STEM-related fields—particularly students from underrepresented groups. To accomplish this, we are proposing a Knowledge Diffusion project. As part of the project, we will synthesize research from social psychology, education, and vocational studies related to student participation in STEM fields of study. The proposed project will consist of the following: 1) examination of the potential application of social psychological, educational, and vocational theories to STEM participation, 2) integration and comparison of current knowledge on best teaching practices across STEM-related disciplines, 3) the synthesis of 1 & 2 to examine how these two bodies of knowledge can be integrated to increase student participation and retention in STEM and 4) the diffusion of the results of this synthesis to a wide-range of STEM educators.

We will identify both empirical and theoretical literature from psychology, education (particularly STEM education), and vocational studies with applicability to participation and retention in STEM. We have four criteria for inclusion. To be incorporated into our synthesis the theories and empirical work must meet four criteria.

- The research or theory must potentially link self-concept, i.e. self-efficacy and personal values, to STEM learning. Although there does not need to be an explicit reference to self-concept, the work must clearly relate to student self-concept in some manner. This criterion will be considered met if self-concept is linked in any literature to the topic in the article under consideration, even if that specific article does not explicitly mention self-concept. For example, several studies indicate that providing opportunities for hands-on-learning improves self-efficacy (Crippen, & Earl, 2007; Johnson, & Liber, 2008; Luzzo et al, 1999). So a study examining problem-based learning in STEM would be included in the synthesis even if it made no mention of self-efficacy since other research provides the link.

- The teaching strategy or theory must be applicable to adult learners. This does not necessarily exclude research pertaining to K-12, but does require that there is theoretical argument that the technique or finding could also apply to adult learners. For instance, Eccles' Expectancy-Value Theory (Eccles & Wigfield,

2002) is typically applied to adolescents, i.e. Weisgram & Bigler (2006). However, nothing in the model precludes its application to adults.

- Similarly, the research or theory must also be applicable to STEM learning. Thus, we would not include teaching strategies that clearly could have no application in a STEM classroom. However, we might include research from non-STEM disciplines if they could inform STEM instruction. An example of this might be research indicating that problem based learning improved reading literacy. Problem-based learning is a strategy easily adaptable to a STEM classroom, so even if the research examined improvement in reading literacy it could still pertain to STEM instruction.
- Fourth, the research or model must have the potential to address gender and racial disparities in STEM participation, achievement, and retention. For theoretical work this requires that the theory must be able to address individual difference in self-concept. For empirical studies this would entail the study providing information on racial and/or gender differences. Empirical work will not need to specifically test for gender or racial differences, but the demographics of the sample must be sufficiently reported to allow examination of any potential differences by gender and/or race.

- Additionally, any theoretical work must have empirical evidence of its validity. For example, there are numerous empirical studies supporting Bandura's Social Cognitive model of motivation (1997), Expectancy-Value Theory (Eccles & Wigfield, 2002), and Social Cognitive Career Theory (Lent, Brown, & Hackett, 1994).

The Intellectual Merits of the synthesis proposed here lie in the integration of knowledge from disparate disciplines as they relate to STEM education. Currently, theorists and researchers from many areas are simultaneously attacking issues with direct application to increasing student participation in STEM in addition to ameliorating gender and racial disparities in STEM participation. However, there is little to no crosstalk occurring between these bodies of knowledge. This lack of synthesis can result in redundancy of efforts as well as (and possibly more importantly) the development of a body of knowledge that lacks the depth and complexity necessary to solve this very important and difficult problem. In order to fully understand the current lack of participation in STEM, it is necessary to understand how all aspects of the human experience contribute to an individual's decision to pursue an academic and professional career. The project proposed here will contribute to the intellectual body of work regarding participation in STEM by synthesizing bodies of knowledge regarding the cognitive, learning, social and motivational elements of the human experience that my influence participation in STEM.

The Broader Impacts of this project will be actualized through the dissemination efforts. There is general consensus that the United States is experiencing a shortage of STEM professionals and graduate students pursuing STEM careers (e.g. U.S. Department of Commerce, 2005). The proposed project will attack this problem by synthesizing interdisciplinary knowledge and theory related to self-efficacy and personal values as they apply to STEM instruction. We submit that STEM faculty armed with this knowledge may be more successful in responding to individual student needs. This responsiveness could maximize students' participation and retention in STEM, and may also decrease existing gender and racial disparities. Thus, the knowledge gained from this synthesis will have broad impacts on: 1) increasing the participation of underrepresented groups, 2) improving overall retention in STEM, 3) consolidating the understanding of social psychology, vocational and educational research findings on teaching and learning in formal and informal settings, and 4) nationally disseminating the knowledge gained through workshops targeted for STEM faculty at universities and community colleges.

Dissemination Efforts:
We will use several methods to disseminate the results of this synthesis project—workshops, a website, conference presentations, and publications in peer-reviewed journals. The primary method for dissemination will be a one-day workshop format providing information and training to STEM educators regarding the effects of self-concept on students' participation in STEM areas of study. Each workshop will be focused on communicating variables that predict student participation and retention in one area of STEM. Specifically, we will have one workshop for Science educators, and others for Technology, Engineering, and Mathematics respectively. This format will provide educators the opportunity to learn relevant information regarding their instruction methodologies that is also specific to their general content area. As a part of the workshops, we will present specific tools faculty can use to reduce the performance gap between underrepresented groups (i.e., women and minorities) and majority groups.

To increase the benefit of participation for the faculty members, each workshop will also have a presentation from a nationally recognized speaker in that content area. For example, for the "Science" workshop, we will invite someone like Dr. Neal Lane (Senior Fellow in Science and Technology Policy, Rice University) to make a presentation regarding the importance of attracting and retaining students in the natural sciences. For the "Technology" workshop, we will invite someone like Dr. Lydia Kavraki (Noah Harding Professor of Computer Science and Bioengineering, Rice University), who could speak about the elements necessary to attract and support women's participation in Computing. Similar types of invitations will be made for the "Engineering" and "Mathematics" workshops.

Given the large and very diverse population of the Greater Houston area, the faculty who attend these workshops will necessarily be those same faculty who have individuals from underrepresented groups in their classes. As illustrated in Tables 1 and 2, the community colleges and universities in the Greater Houston area have a large number of students from underrepresented groups in STEM—both minority (Table 1) and female (Table 2) students. In addition to faculty from the greater Houston area, we will invite faculty from across the state and the nation to participate in the workshops.

Table 1. *Racial breakdown for Universities and Community Colleges (CC) in the Greater Houston Area.*

	San Jacinto CC-Central Campus [a]	College of the Mainland [a]	Houston CC [a]	Alvin CC [a]	UH-Clear Lake [b]	UH-Main Campus [c]
White	52.9%	58.8%	25.0%	67.0%	60.5%	38.5%
International	3.2%	0.1%	8.0%	0.1%	6.9%	7.3%
American Indian	0.4%	0.7%	0.0%	0.1%	0.5%	0.4%
Asian/Pacific Islander	4.0%	2.5%	12.0%	2.0%	5.7%	19.5%
African American	5.5%	16.0%	25.0%	11.0%	10.5%	13.2%
Hispanic	33.5%	19.6%	27.0%	19.0%	15.9%	19.3%
Other	0.6%	2.5%	3.0%	0.1%	0.0%	1.8%

[a] *2006 College Profiles Public Community and Technical College of Texas*, 2007
[b] Tiu, S., Johnson, P., Qumsieh, M., Salinas, P., & Smith, J., 2007
[c] *University of Houston Fall 2006 Fast Facts*, 2006

Table 2. *Gender breakdown for Universities and Community Colleges (CC) in the Greater Houston Area.*

	San Jacinto CC-Central Campus [a]	College of the Mainland [a]	Houston CC [a]	Alvin CC [a]	UH-Clear Lake [b]	UH-Main Campus [c]
Male	42.7%	41.1%	N/A	52.0%	34.3%	48.2%
Female	57.3%	58.9%	N/A	48.0%	65.7%	51.8%

[a] *2006 College Profiles Public Community and Technical College of Texas*, 2007
[b] Tiu, S., Johnson, P., Qumsieh, M., Salinas, P., & Smith, J., 2007
[c] *University of Houston Fall 2006 Fast Facts*, 2006

The second dissemination method we will utilize is a website. The website will have the findings of this project archived and organized in a manner that will be easily accessible by researchers and faculty from all disciplines. It will also have online videos of the workshops so those who are not able to attend will have access to the information presented there.

To further disseminate the findings of the proposed project, the PI and Co-PIs will make presentations at STEM related conferences—particularly conferences that have education of STEM fields as their main focus. This will facilitate the dissemination of the knowledge to a broader audience and allow for continued discourse regarding methods of applying and integrating the new findings into STEM curriculum.

The final method of dissemination will be through peer-reviewed journal submissions. There are several journals focused on the education of different STEM related fields and publications through these journals will insure the broadest dissemination of this information.

References

Synthesis and Diffusion of Knowledge

Linking Self-Concept, Education, and Student Participation in STEM.

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