## Proposal Details

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### Secondary Investigator(s)

### Project Description I

Title:

Modeling Student Entrance into STEM Fields of Study at Community Colleges and Four-Year Institutions: Towards a Theoretical Framework of

## Statement of the research problem and national importance:

Without question, America's ability to maintain its global competitiveness within science, technology, engineering, and mathematics (STEM) fields is an issue of national importance. Often discussed in the context of human capital (National Science Board, 2010), critical issues for the nation's STEM infrastructure center on a recognized need for building STEM workforce capacity (National Academies 2005 "Rising Above the Gathering Storm" Committee, 2010). Support for this cause has been levied through investments in educational programming, many of which are focused on postsecondary education.

The demand for graduates in STEM fields continues to grow at a rapid rate. According to the National Science Foundation (2010), the employment rate in science and engineering fields rose an average of 3.3% annually between 2004 and 2008 compared to an average 1.3% annual increase in employment in all occupations. This estimated growth ratio is consistent with long-term national trends but trails increases internationally (U.S. Department of Labor, 2007). Meanwhile, there is indication that although the national demand for motivated high school graduates to enter STEM fields is at its highest, high school seniors' interest in and readiness for STEM fields have been declining (ACT, 2006). American postsecondary institutions are therefore facing an unprecedented need to increase the number of students who study in STEM disciplines.

Although these rising calls have generated a fair amount of empirical interest, most of the research in this vein centers on persistence and attainment among students who have already entered the STEM fields. Not as much empirical attention has been paid to factors relevant to entrance into STEM fields, arguably the first critical step into the STEM pipeline. At the same time, concerns have been raised about participation in these fields of traditionally underrepresented populations such as minorities and first-generation, low-income college students (e.g., Anderson & Kim, 2006; National Academies 2005 "Rising Above the Gathering Storm" Committee, 2010). For many of these traditionally underrepresented student populations, community colleges serve as a stepping-stone to a baccalaureate degree or better career opportunities (e.g., Bailey, Leinbach, Scott, Alfonso, Kienzl, & Kennedy, 2004; Wang, 2009). In this sense, community colleges represent a unique opportunity in the preparation of a future STEM workforce that reflects the diversity of the U.S. population. Much of the effort in broadening STEM participation, particularly among underprivileged student groups, will rely on the nation's community colleges. Therefore, research that deals with the STEM pipeline should not overlook these institutions. However, current empirical research on STEM education at the postsecondary level mainly focuses on four-year institutions, whereas community colleges and their students are underrepresented in the literature.

Given the pressing national concerns facing STEM education, it is pivotal to provide rigorous academic programs and support mechanisms that prepare students to enter these challenging and important fields in both two-year and four-year institutions. Needless to say, this important educational endeavor will rely on collective, concerted, and well informed efforts by the nation's secondary schools, community colleges, and four-year institutions. As such, theoretically based work from a K-16 perspective is needed to better understand boosters and barriers to students' entrance into STEM fields of study. Towards that end, this project proposes and tests a theoretical model of STEM participation that examines factors shaping the decision to pursue STEM fields of study among two student groups—community college entrants and four-year institution entrants—using a nationally representative sample of high school graduates from 2004. Particular attention will also be given to the varying effects of high school and postsecondary factors by gender, race/ethnicity, socioeconomic status, and first-generation status.

Integrating prior literature and the social cognitive career theory, this study advances previous empirical efforts on STEM education in several ways. First, it proposes an interdisciplinary model in order to strengthen the theoretical understanding of the factors influencing college student choices specific to STEM. Second, the results from this study add to the knowledge regarding community college students who enter STEM fields, a largely ignored population in the national discussion on STEM education. In addition, the study is timely because the data sample is recent and its results have implications for improving K-12 and postsecondary practices and activities that promote participation in STEM, particularly those that target underrepresented student populations.

## Review the literature and establish a theoretical grounding for the research:

*Research on STEM Education*

STEM education has garnered close scholarly attention. Numerous studies have revealed the disproportionally high attrition rates for women and minorities and the bachelor's degree completion gap in STEM disciplines at four-year institutions across the nation (e.g., Anderson & Kim, 2006; Higher Education Research Institute, 2010; Seymour & Hewitt, 1997). In addition, researchers have also highlighted theoretical reasons that students persist or leave a STEM field of study, such as early exposure to and proficiency in math and science (Adelman 1999; Anderson & Kim, 2006; Hagedorn & DuBray, 2010), high school curriculum (Elliott, Strenta, Adair, Matier, & Scott, 1996), advanced courses in math and science

(Ellington, 2006), information early in the career search process (Holland, 1992), the types of opportunities, experiences, and support students receive in college (e.g., Chang, Sharkness, Newman, & Hurtado, 2010; Seymour & Hewitt 1997), institutional selectivity (Chang, Cerna, Han, & Sáenz, 2008), faculty quality and diversity (Leach, 2010), and classroom experiences (Cabrera, Colbeck, & Terenzini, 2001).

Despite the wealth of research on persistence and completion in STEM fields, less focus has been given to entrance into a postsecondary STEM discipline. Existing research shows that the choice to pursue STEM related fields is affected by math and science related interest and self assessment (Seymour & Hewitt, 1997), math and science completed during high school (Maple & Stage, 1991), social background (Ware & Lee, 1988), and parental education (Gruca, Ethington, & Pascarella, 1988). The most comprehensive study to date on students who enter STEM at the national level was conducted by Chen and Weko (2009). Utilizing three IES longitudinal datasets, the authors found that the percentage of students entering STEM fields was higher among male students, younger and dependent students, Asian/Pacific Islander students, foreign students or those who spoke a language other than English as a child, and students with more advantaged family background characteristics and stronger academic preparation than among their counterparts. However, given the descriptive nature of the study, factors influencing STEM entrance beyond demographics were barely examined. Another recent study (Crisp, Nora, & Taggart, 2009) found that decisions to declare a STEM major and earn a STEM degree were uniquely influenced by students' gender, ethnicity, SAT math score, and high school percentile. Despite these commendable empirical efforts, relatively less is known about why students enter STEM fields.

*Community Colleges and STEM Education*

Many STEM-focused students begin their postsecondary career at a community college (Hagedorn & Dubray, 2010), and more than 40% of recent science and engineering graduates have attended community colleges (Tsapogas, 2004). Federal agencies, researchers, and policymakers recognize the importance of community colleges in the STEM pipeline (Burke & Mattis, 2007; Cohen & Brawer, 2008; Starobin & Laanan, 2010; U.S. Department of Labor, 2007). Recent studies have begun to explore the state of STEM education in community colleges, especially regarding female students' underrepresentation among STEM-related associate's degree earners and possible reasons for this underrepresentation such as a lack of emotional and institutional support (e.g., Hardy & Katsinas, 2010; Lester, 2010), self-concept (Starobin & Laanan, 2005), and interaction with faculty (Starobin & Laanan, 2008). However, still little empirical research has been conducted on factors influencing the entrance into STEM fields among students beginning at community colleges.

Overall, the state of research on STEM education represents substantial efforts among researchers towards a better understanding of the underlying factors that influence student success along the STEM pipeline. However, not enough focus has been placed on understanding entrance into STEM fields of study. In addition, community colleges have not received much empirical attention. The barriers and boosters to students choosing STEM fields at both community colleges and four-year institutions are unclear. As a result, knowledge is scant on how to broaden STEM participation, essentially the first critical step towards building a viable STEM pipeline. This proposed project will address these limitations by focusing on entrance into STEM fields and identifying the characteristics and factors associated with student decision to pursue STEM in both community colleges and four-year institutions.

*Social Cognitive Career Theory*

This study is also grounded in Social Cognitive Career Theory (SCCT), which offers an appropriate theoretical lens to study the issue of STEM choice (Lent, Brown, & Hackett, 2000). Based on Bandura's (1986) general social cognitive theory, SCCT underscores the interrelationship among individual, environmental, and behavioral variables that are assumed to undergird academic and career choice (Lent & Brown, 2006). Key factors in SCCT include self-efficacy beliefs, outcome expectations, interests, environmental supports and barriers, as well as choice actions (Lent, Sheu, Gloster, & Wilkins, 2010). SCCT has been applied in a small number of studies on STEM related academic choice intentions (e.g., Gainor & Lent, 1998; Lent, Lopez, Lopez, & Sheu, 2008). Although this set of studies suggest the validity of SCCT as an explanatory framework for understanding STEM interests and choices, they are largely limited by cross-sectional designs and single institution data (Lent et al., 2010). Based on a national longitudinal database, this study incorporates key constructs in SCCT to build a conceptual model of STEM participation and will capture the nature of the relationships between the theoretical variables over time.

*Theoretical Framework*

Utilizing a longitudinal, nationally representative sample, this study proposes a conceptual framework for understanding the decision to choose STEM fields of postsecondary study among recent high school graduates. Integrating prior literature and SCCT, the theoretical model hypothesizes that students' high school exposure to STEM courses, math self-efficacy beliefs, and high school math preparation influence their interest in pursuing STEM fields, which in turn affects their actual choice of STEM fields of study. In addition, the model theorizes that entrance into STEM fields is also directly influenced by students' initial postsecondary experience and their high school math preparation. A graphic representation of the model is presented in Appendix A.

SCCT posits that the determination to produce a particular choice can be explained as a result of interests and self-reference beliefs. Based on prior studies (e.g. Adelman, 1999), high school math learning has evolved as a particularly promising factor influencing choice of STEM fields of study. Therefore, this study theorizes that students' math self-efficacy beliefs and math preparation from high school, mutually influencing each other, both give rise to students' interest in or intention to pursue STEM fields upon postsecondary entry, which is also influenced by the amount of academic exposure to STEM courses during high school.

After students start their postsecondary career, their pursuit of STEM as an academic goal responds to contextual support and barriers, social, academic, or financial. In particular, since K-12 assessments and the academic requirements of postsecondary institutions are often at odds (Goldrick-Rab, 2007), students transitioning into postsecondary education need to navigate a series of demands, such as financial aid, need for remediation (particularly among community college entrants), and interaction with faculty and academic advisors. The outcomes of this process might present either barriers or support and thus impact academic choice behavior by STEM-aspiring students. These initial college experiences at students' first postsecondary institution are presumed to directly shape their decisions to pursue STEM fields of study. The theoretical model also incorporates the effects of demographic background on STEM participation.

## Describe the research method that will be used:

*Research Questions*

The purpose of this study is to understand the direct and indirect influence of high school learning experience as related to STEM, math self-efficacy beliefs, and initial postsecondary experiences on entrance into STEM fields of study in college. I have developed an *a priori* path analysis model based on relevant research literature and the social cognitive career theory and will test that model in this study. Specifically, the following interlocking research questions guide the analyses:

1. What are the relationships among high school exposure to STEM courses, math preparation, math self-efficacy beliefs, interest in pursuing STEM upon entry into postsecondary education, and entrance into STEM fields of study?
2. Taking into account the relationships described in question 1, how are students' initial postsecondary education experiences (such as remediation, receipt of financial aid, and academic interaction) related to choice of STEM fields?
3. How do these relationships vary across different gender, racial/ethnic, and socioeconomic groups?
4. How does the theoretical model fit two-year and four-year college student populations?

*Data Source and Sample*

Data for this study come from the Education Longitudinal Study of 2002 (ELS: 2002), which was designed to study the transition of young people from high school into postsecondary education and the workplace. ELS: 2002 started with a nationally representative cohort of high school sophomores. The sample was then augmented in the 2004 first follow-up study to represent high school seniors. In 2006, roughly two years after high school, the second follow-up study collected data about access to postsecondary institutions, students' choices of enrollment and college major, and some other aspects of their college experience.

This study focuses on the ELS spring 2004 high school seniors who participated in the second follow-up interview and who had enrolled in a postsecondary institution by 2006. Of approximately 14,000 members of the 2004 senior cohort, about 12,500 (89.3%) responded to the second follow-up interview. For the purpose of this study, I retained a total of 9,687 (out of 12,500 eligible) students who had reported postsecondary attendance (two-year or four-year) by 2006. This sample was further divided into two analysis groups: (a) those whose first postsecondary institutions are four-year institutions (6,331; 65%) and (b) those who attend community colleges as their first true postsecondary institutions (3,356; 35%). All analyses will be weighted using the appropriate panel weight (F2F1WT) and therefore will generalize to the population of spring 2004 high school graduates who accessed postsecondary education through either a community college or a four-year institution within two years of high school graduation.

*Measures*

Based on the theoretical model, the following key variables are included in the study:

The key dependent variable: *pursuing a STEM field of study* is a dichotomous variable, recoded from the survey item asking respondents' field of study during the 2006 ELS second follow-up interview.

The focal mediating variable is *interest in pursuing a STEM field*, measured by whether students consider a STEM discipline the most likely field of study upon postsecondary entrance.

Key independent variables include three exogenous independent factors at the high school level: (a) *exposure to STEM courses*, measured by the number of units in engineering, mathematics, and science technologies, (b) *high school math preparation*, measured by hours spent on math homework as well as high school math standardized score, and (c) *math self-efficacy beliefs*, represented by five items measured on a Likert-type scale that address students' self-efficacy beliefs in taking math tests, mastering math skills, and completing math assignments.

In addition, three variables are used to operationalize initial college experiences: academic interaction, remediation, and receipt of financial aid. Academic interaction is measured by the frequency of interacting with faculty about academic matters and the frequency of meeting with advisors about academic plans. Student interaction with faculty and academic advisors positively influences numerous student outcomes (Astin, 1993; Chang, 2005; Lamport, 1993; Terenzini, Pascarella, & Blimling, 1999). Given the focus of this study, such interactions may provide particularly needed support for students to clarify and confirm their choice of field of study. Remediation is measured by whether students took remedial courses to improve reading, writing, and math skills. For many students, especially community college beginners, remediation is a necessary part of the curriculum (Pascarella & Terenzini, 2005). However, research on the effect of enrolling in remedial courses has produced mixed results (Adelman, 1999; Bahr, 2008; Bailey & Alfonso, 2005; Long, 2005). Examining the relationship between remediation and student choice of STEM in this study will provide targeted, context-based research evidence regarding the effectiveness of remediation in sustaining students' academic aspirations. In addition, the receipt of financial aid affects student academic choices (e.g. DesJardins, Ahlburg, & McCall, 2006; Ishitani & DesJardins, 2002). ELS specifies the financial aid status (loan, grant, and work-study) of students; thus, the receipt of financial aid is based on their first-year aid status.

This study also includes a number of demographic and control variables. For a complete list of the variables to be used and their descriptions and associated ELS labels, see Appendix B.

*Analytical Strategies*

After initial data screening and cleaning, I will proceed with data analysis as follows:

First, I will compute descriptive statistics for each of the key variables and disaggregate the data by gender, race, first-generation status, and socio-economic status (SES). These descriptive statistics provide a general profile of the ELS 2004 high school senior cohort's participation in STEM two years after high school graduation and help identify any variation in experiences across gender, race/ethnicity, first-generation status, and SES.

Following the descriptive analysis, I will obtain support for the construct validity for the latent variables in the model through a confirmatory factor analysis and compare naturally emerging structures within the data with the theoretical structures posited in the *a priori* model. I will then test the proposed conceptual model for both community college and four-year college student populations, using structural equation modeling (SEM) analysis. Accounting for measurement errors which are usually present in survey data based on self-reporting, SEM simultaneously defines latent, multidimensional constructs (such as math self-efficacy) and observed variables (such as choice of STEM), and also tests the theoretical links and their directions among the study's key variables. I will use maximum likelihood estimation procedure for parameter estimation in the SEM analysis, as this estimation method is robust to the violation of the multivariate normal distribution assumption (Chou, Bentler, & Satorra, 1991), which is likely the case in this study. Following Byrne (1998), the overall model fit will be examined using chi square ($\chi^2$), comparative fit index (CFI), Tucker-Lewis Fit Index (TLI), root-mean-square error of approximation (RMSEA), and a weighted root mean square residual (WRMR). I will also examine the impact of student demographic characteristics by adding the covariates (e.g., gender, ethnicity, enrollment status) into the model and studying modification indices for possible significant direct effects.

Although SEM is traditionally suited for analyzing continuous variables, recent software and methodological developments have largely extended the application of SEM in analyzing all types of variables—continuous, ordinal, or nominal—as present in this study. I will conduct the analyses using *Mplus* 6.1, a statistical software package capable of modeling a mixture of observed continuous, ordinal, nominal scale variables, and latent variables, based on generalized linear models as a unifying framework for both continuous and categorical variables, where the latter are first transformed into continuous linear functions and subsequently modeled by SEM (Kupek, 2006; Muthén & Muthén, 2007). In addition, *Mplus* contains statistical tools that take into account the complex sampling design for both survey weights and the clustering nature of the ELS data.

Uploaded Appendix Document(s):

- Appendix B. List of Variables
- Appendix A. Theoretical Model for the Study

## Project Description II

Will you use NCES target dataset? Yes

Please check all NCES datasets that apply
- Educational Longitudinal Study of 2002 (ELS: 2002)

Explain why each dataset best serves this research. Include a variable list for each dataset used.
This study draws upon data from the first and second follow-up interviews of the Education Longitudinal Study (ELS: 04/06) to examine how choice of STEM fields is related to a variety of high school and postsecondary factors. Given its focus on transition from high school to postsecondary education and the recentness of its longitudinal data, ELS is the most appropriate dataset for this study. To fully understand student learning, motivation, interest, and choice as related to STEM fields, it is necessary to follow the same individuals from high school into college. The longitudinal data from ELS provide a thorough empirical description of student experiences relevant to STEM education in high school and early years of college. In addition, focusing on relatively recent high school graduates, ELS data will address the proposed research in a timely manner and produce results that are more relevant to current STEM-related educational policies. Given this study's focus on entrance into STEM fields among recent high school graduates, ELS is an ideal data source to test the proposed theoretical model. Based on the results from this study (which is the first phase of a larger research agenda focusing on STEM education), I will modify and expand the model as necessary in studying persistence, attainment, and workforce participation along the entire STEM educational career among both two-year and four-year college students, as future waves of the ELS data become available. The list of variables to be used in the study is provided in Appendix B.

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Will you use NSF target dataset? No

Explain why each dataset best serves this research. Include a variable list for each dataset used.

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Will you address the NPEC focus topic? Yes

If yes, please briefly describe:
This study addresses the 2011 NPEC topic by focusing on the entrance into STEM fields among both two-year and four-year college students and by modeling the effects of a number of important postsecondary variables, such as remedial practices, on STEM entry. The emphasis on entrance into STEM highlights the important first step towards successfully completing a postsecondary STEM education. By identifying the relationships between postsecondary practices (financial aid, remediation, etc.) and STEM participation at both community colleges and four-year institutions, this study provides a nuanced understanding of the effectiveness of these practices in sustaining students' aspirations to pursue STEM fields.

## Project Description III

Provide a timeline of key project activities:

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| **2011 Activities** | |
|---|---|
| May–June | • Receive funding and prepare data for analysis |
| July–October | • Complete descriptive analysis and factor analysis<br>• Complete SEM analysis |
| November–December | • Write up results and prepare statistical tables<br>• Prepare and submit mid-year progress report to AIR |
| **2012 Activities** | |
| January–February | • Write the results and discussion sections<br>• Refine literature review and research methods sections as needed |
| March | • Complete a research manuscript based on the study and present the study at AERA, contingent upon proposal acceptance<br>• Publish the manuscript as a working paper on the website of the Wisconsin Center for the Advancement of Postsecondary Education (WISCAPE) |

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|---|---|
| April | • Finalize the manuscript based on feedback from UW-Madison and WISCAPE colleagues and AERA<br>• Submit the manuscript to *Research in Higher Education* |
| May–June | • Publish a policy brief on WISCAPE website<br>• Present the refined manuscript at AIR annual forum<br>• Prepare and submit final report to AIR |

## List deliverables such as research reports, books, and presentations that will be developed from this research initiative:

The following deliverables will result from this research initiative:

- Conference presentations at the 2012 AERA and AIR annual meetings;
- Research reports to AIR, including mid-year progress report and final report;
- Working paper(s) to be published on the website of the Wisconsin Center for the Advancement of Postsecondary Education (WISCAPE);
- Policy belief focusing on the study's policy implications, also to be published on WISCAPE website;
- Research article(s) to be submitted for publication in *Research in Higher Education*, *Review of Higher Education*, and/or *Journal of Higher Education*.

## Describe how you will disseminate the results of this research:

Manuscripts based on this study will be submitted for publication in *Research in Higher Education* and *Review of Higher Education* or *Journal of Higher Education*. In addition, the research papers will be disseminated as working papers through the Wisconsin Center for the Advancement of Postsecondary Education (WISCAPE) where I serve as a scholar. A policy brief that focuses on the policy implications of the study will also be published through WISCAPE. All WISCAPE papers will be distributed via the center's website, e-newsletter (3,000+ subscribers), targeted e-mail announcements, and limited print production. As previously described, results of this research will also be presented at two national conferences including AIR and AERA.

## Provide a reference list of sources cited:


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## IRB Statement

### Statement of Institutional Review Board approval or exemption:

The IRB at the University of Wisconsin-Madison specifies that research projects involving analysis of secondary data from NCES do not require prior IRB approval.

## Statement of Use of Restricted Datasets

This study will employ the restricted-use data from the first and second follow-up studies of ELS. I am currently authorized to use the restricted-use ELS data through a site license at the Wisconsin Center for the Advancement of Postsecondary Education.

## Biographical Sketch

### Xueli Wang's Biography Sketch

Dr. Xueli Wang is an assistant professor in the Department of Educational Leadership and Policy Analysis at the University of Wisconsin-Madison and a scholar at the Wisconsin Center for the Advancement of Postsecondary Education (WISCAPE). She holds a Ph.D. in Higher Education and a graduate minor in quantitative research methods from The Ohio State University. Her teaching assignments at UW-Madison include Community Colleges, College Students, Educational Planning, and Research Methods. Her research has addressed the secondary-postsecondary nexus and the intersection between motivational beliefs, social disadvantage, and college experience and success, with a particular focus on community colleges and transfer students. Part of her current research agenda focuses on the role of community colleges in STEM education, using national data (such as ELS 04/06 and future waves of ELS and BPS) and data from the Wisconsin Technical College System. As one of the early projects in this broader research agenda, this proposed research will largely inform and promote her research efforts in the field of STEM education using both national and state data.

While pursuing her Ph.D. at Ohio State, Wang was selected as an AIR/NCES/NSF Fellow to attend the 2006 Summer Data Policy Institute and gained extensive knowledge and skills in using NCES and NSF national survey data. In 2007 – 2008, she received a dissertation fellowship in the amount of $15,000 from the AIR/NCES/NSF/NPEC grant program in support of her NELS: 88/2000 based dissertation research that examined factors associated with the educational pathway and long-term success of baccalaureate aspirants attending community colleges.

## Budget Requirements

### Xueli Wang' Budget

Personnel-Time on Project
%(FTE) Academic Year: 25.00
%(FTE) Summer: 50.00

Personnel-Salary & Benefits
Academic Year: $ 86211.00
Summer: $ 28737.00

### Graduate Research Assistant's Budget

Personnel-Time on Project
%(FTE) Academic Year: 0.00
%(FTE) Summer: 0.00

Personnel-Salary & Benefits
Academic Year: $ 0.00
Summer: $ 0.00

Total Salary and Wages: $35921.25

Travel: $1057.00
Other travel related expenses: $0.00
Other research expenses: $2400.00
Total Request: $39378.25

## Funding History

This proposed study has not received any prior or current funding. I received a 2006 Summer Data Policy Institute Fellowship and a 2007 – 2008 dissertation grant, both from the AIR grant program. Two research articles based on my AIR-funded dissertation project have been published in peer-reviewed journals including *Research in Higher Education*. A third article is under revision at another top-ranked journal. Currently, as a new tenure-track assistant professor at UW-Madison, I am broadening my research agenda while delving deeper into the role of community colleges in educational and workforce development. Funding for this research will therefore greatly help me advance my research on STEM related issues, especially the intersection between STEM education and community colleges.