



Student Innovation and Persistence in STEM Majors: What Works and What Doesn't for Community College Students

Dr. Gisele Ragusa, University of Southern California

Gisele Ragusa is a Professor of Engineering Education at the University of Southern California. She conducts research on college transitions and retention of underrepresented students in engineering and also research about engineering global preparedness and engineering innovation. She also has research expertise in STEM K-12 and in STEM assessment. She chairs USC's STEM Consortium.

Student Innovation and Persistence in STEM Majors: What Works and What Doesn't for Community College Students

Abstract

There is a critical need for more students with engineering and science majors to enter into, persist, and graduate from postsecondary institutions. Increasing the diversity in engineering and science is also a profound identified need. According to national statistics, the largest groups of underrepresented minority students in engineering and science attend United States public higher education institutions and in particular the community colleges. Recent research has indicated that students from these populations who are strong problem solvers, and who understand how to seek assistance and navigate college campuses, are most likely to persist to degree completion. Accordingly, this research examined a sample of non-traditional college students enrolled in science and engineering programs in six urban community colleges to determine (a) the types and frequency of support practices they utilized, (b) how such practices influenced their achievement, persistence and transfer status to four-year colleges and universities, and (c) how in turn their propensity for innovation and creative problem solving affected such choices and persistence. The study analyzed the impact of pedagogical support practices—practices designed to foster successful transfer from community college to four-year colleges and universities, and how students' innovative capability affected such transfer capacity. The goals were: (a) to understand whether particular pedagogical support practices were effective in offering non-traditional students a program that enabled them to remain in engineering and science majors and to transfer to a four-year college or university, and (b) to determine if students' propensity for innovative problem solving influenced use of pedagogical practices and ultimately, transfer persistence. The research targeted four research questions: (1) What are the patterns of pedagogical practices that community colleges employ to enhance students' transfer success in engineering and science? (2) How do students' creative and innovative problem-solving approaches influence the choices that they make in using pedagogical support practices? (3) What are the impacts of pedagogical practices and differences among pedagogical practices, on persistence toward students' transfer to colleges and universities? (4) How do students' creative and innovative problem-solving approaches influence their persistence toward transfer to engineering and science programs at four-year universities?

This research is ongoing and involves a two-stage study in which in stage one, the types of pedagogical support practices used in community colleges were analyzed and taxonomized at four community colleges. Results of this part of research led to the delineation and refining of three categories of student pedagogical support: (1) College attending support, (2) Program planning and execution support, and (3) Classroom and program performance support. These categories led to development and refinement of a college level pedagogical practice taxonomy and inventory which was used in stage two of the research in which data was collected on 2476 community college students in STEM majors. The intent of stage two of the research is to determine the role of students' creativity and propensity of innovation had on their persistence and the impact that use of particular pedagogical practices had on their persistence, creativity and propensity for innovation in STEM. This work is ongoing and 6 community colleges are now involved in the study.

Structural equation models (SEMs) have been developed and updated with multiple

rounds of data collection. These models have been used for data analyses with one containing grade point average (as a proxy for achievement) as the outcome of interest and the second with engineering creativity and propensity for innovation as the outcome of interest, both of which address the study's research questions. Thus far the two models indicate that use of pedagogical practices impact students' creativity and propensity for innovation and propensity for innovation impacts students' achievement (with GPA as a proxy.) Notably, students' background characteristics also have pronounced impacts on the two outcomes of interest. In addition to informing engineering education research, this research informs community college faculty and student affairs personnel on which support practices best support students in STEM majors to transfer to colleges and universities and how students' creativity and propensity for innovation affects such transfer persistence.

[Portions of this paper in the review of the literature and research design have been reprinted from the 2015, 2016 and 2017 ASEE Poster Session Papers which provide preliminary material for the reader.]^{1,2}

Motivation and overview

There is a critical need for more students with engineering and science majors to enter into, persist, and graduate from postsecondary institutions. Increasing the diversity in engineering and science is also a profound identified need.³ According to national statistics, the largest groups of underrepresented minority students in engineering and science attend the United States public higher education institutions and in particular community colleges.⁴ Recent research has indicated that students from these populations who are strong problem solvers, and who understand how to seek assistance and navigate college campuses, are most likely to persist to degree completion. The present research underscores the importance of innovative problem solving for students to persist in engineering majors.⁵ Accordingly, this engineering education research examines a sample of non-traditional college students enrolled in science and engineering programs in six urban community colleges to determine (a) the types and frequency of support practices they utilize, (b) how such practices influence their achievement, persistence and transfer status to four-year colleges and universities, and (c) how in turn the students' propensity for innovation and creative problem solving affects such choices and persistence. This paper presents on four years of a multistage research project funded by the National Science Foundation (NSF). The value of the study's findings depends largely on an exploratory research design, which analyzes the pedagogical practices—practices designed to foster successful transfer from community college to four-year colleges and universities and how students' innovative capability influences such transfer capacity. The goals of this research are: (1) to explore the pedagogical practices used to support non-traditional students in community colleges to persist in engineering and science majors, (2) to understand whether such practices are effective in offering non-traditional students a program that enables them to persist in engineering and science majors and to transfer to a four year college or university, and (3) to determine if students' propensity for innovation and creative problem solving influences a particular use of pedagogical practices and ultimately, transfer persistence. This study builds upon a pilot study that was conducted that focused on one community college, student persistence and propensity for innovative problem solving, and extends this research to a multidimensional, comparative study with six community colleges. The research targets five

research questions:

- (1) What are the patterns of pedagogical practices that community colleges employ to enhance students' transfer success in engineering and science?
- (2) Are there discernable profiles of non-traditional students enrolling in engineering and science majors in community colleges that utilize these pedagogical practices?
- (3) How do students' creative and innovative problem solving approaches influence the choices that they make in using pedagogical support practices?
- (4) What are the impacts of pedagogical practices and differences among pedagogical practices, on persistence toward students' transfer to colleges and universities?
- (5) How do students' creative and innovative problem solving approaches influence their persistence toward transfer to engineering and science programs at four-year universities?

This is a “work in progress” manuscript.

Critical factors affecting community college students

Based on a review of the literature and the authors' research over the last decade, several “givens” undergird the argument for this engineering education study: (1) Community colleges continue to grow more rapidly than other postsecondary sectors; (2) growth in demand for postsecondary education is increasing, while science and engineering enrollments are not presently growing; and (3) future increases in enrollments will be composed significantly of “non-traditional” students.⁷ Each factor is discussed briefly below.

Ongoing growth of community colleges

While some of U.S. community college growth has leveled in the last two years, the nation has seen a tremendous growth in the past 15 years in this sector. Currently, community colleges serve more first-generation college students, those who are traditionally underrepresented in science technology, engineering and math (STEM) and others with financial needs than four-year universities. According to the American Council of Community Colleges, full time enrollment in community colleges remain stable, with approximately 8,000,000 students enrolled full time, yet part time enrollment is on the rise.⁷ Importantly, community colleges in the state in which this research is being conducted enroll 2.6 million annually, roughly 32.5% of the entire sector, and therefore such community colleges often inform national trends.

Community colleges enroll some of the neediest students nationally with 37% of all Pell Grant recipients during the first quarter of 2014 enrolled in community colleges, a share that increased by 3% compared to the same period last year.⁸ Of all degrees completed by those who initiated their experiences in community colleges, only 17% of all degrees completed were in STEM fields compared to 37% in social sciences and humanities fields.⁹

Increasing importance of postsecondary education for everyone

The present research would not be so vital were it not for the reality that the country's economic and social well being increasingly depends on the skills and knowledge that each citizen acquires. What one earns depends increasingly on what one learns. Rises in the wages of college graduates relative to high school graduates demonstrate this growing relationship between learning and earning. This is especially the case in the technical fields. Increasingly, those individuals with more formal education earn more and the differential is widening.⁹ The earnings of prime working-age men (30–59) with at least a bachelor's degree, like their female counterparts, have increased, but at a slower rate than women. In contrast, the earnings of men with some college or less have seen declines in their inflation-adjusted earnings.¹⁰ The earnings advantage of bachelor's degree holders over high school graduates increased by about 36% between 1979 and 2001, reaching 76%.¹⁰

As the U.S. gradually evolves from an industrial economy to a global knowledge economy, a significantly higher level of education for much larger proportions of society is becoming a necessity—for each individual and for the collective benefit of all individuals. This trend has multiple direct implications for higher education.¹¹ This is particularly important for STEM workforces. Demand for “employment-relevant, technologically focused” postsecondary education programs is increasing, raising the question of whether the U.S. postsecondary education system can respond. This phenomenon calls into question the public's confidence that U.S. higher education can respond sufficiently to these growth demands, especially in engineering and the sciences.

While the U.S. has historically led the world in the quality, scale, and accessibility of postsecondary education, that lead is diminishing, particularly in light of these added demands.¹² As framed by the Commission on The Skills of the American Workforce, America's pipeline is “leaky.”¹³ For every hundred 9th graders, 40 enroll directly in college. Of those who enroll, only 27 continue enrollment beyond their first academic year. Of those who continue beyond year

one, only 18 earn a bachelor's degree within six years.¹² These proportions represent improvements in the U.S. educational system over the last half-century, but comparable improvements in the educational systems of other nations have been greater.¹³ The United States is now tenth of industrialized countries in terms of college going, therefore higher education policies that promote “more of the same” will soon be inadequate.¹⁴

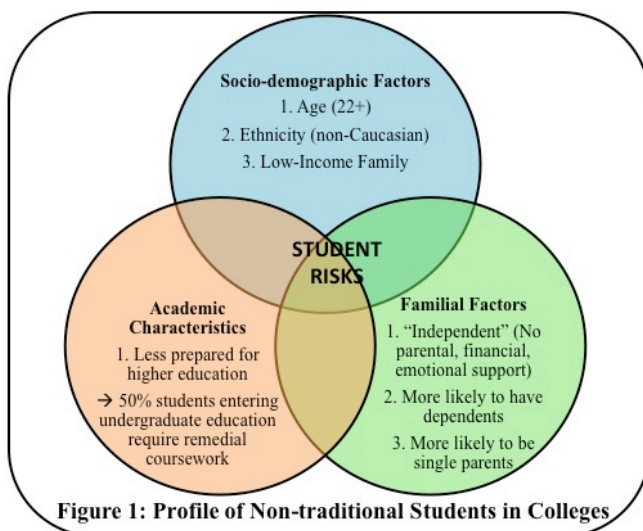


Figure 1: Profile of Non-traditional Students in Colleges

Need for increased enrollments of non-traditional students

People with education, social capital, and means to pursue postsecondary education continue enrolling in colleges; however, the challenge to postsecondary education now is to attract those with fewer inherent advantages, especially where efforts to diversify the workforce are of import. Hence, growth in enrollments is increasingly composed of “non-traditional students” or students with backgrounds not historically well-represented in higher education. “Non-traditional” college students for the purposes of this engineering education study refers to a students with a collection of characteristics that depart from the stereotypical characteristics of college undergraduates which are: 18–22 years of age, Caucasian, from at least a middle-income family, single, successfully completing high school with above average grades, and with relatively little need for separate financial assistance.¹⁵ Departures from this traditional student profile are empirically considered “risk factors” which are associated with reducing the likelihood of successful admission in, retention in, and completion of programs in higher education, and especially in STEM. Consider age as an illustration of this profile. “Undereducated” adult students constitute a large and growing proportion of the nation’s workforce. Of the more than 200 million adults in the U.S., only 27.9% held a bachelor’s degree or higher in 2005—approximately one in four people. The percentage of individuals possessing a bachelor’s degree has increased by slightly less than one-half of one percent annually over the past 25 years.¹¹ Additionally, approximately 15% of adults have less than a high school diploma, 31% have a high school diploma only, and 17% have some college experience; and approximately of 28% of adults in the U.S. have a bachelor’s degree. Conversely, currently adult learners greater than 24 years of age comprise about 39% of all higher education enrollments. This non-traditional group is predicted to increase in enrollment in higher education at a rate of 1.6% compound annual growth, while currently, students under 25 years of age comprise about 61% of all higher education enrollments, and are expected to grow only at a rate of 1.1% CAGR.⁹ Figure 1 (above) provides an illustration of the complexities of U.S. non-traditional college student.

Research indicates that non-traditional students, regardless of age, are generally less academically prepared for higher education than their academically focused high school counterparts. Because the overall proportion of individuals above eighteen years of age who seek enrollment in postsecondary programs continues to grow, the risk factors and deficits in academic preparation of new cohorts of students are increasing.¹⁶ This presents a significant burden to postsecondary institutions that admit “under-qualified” students, as is the case with community colleges. Recent higher education statistics have revealed that across all U.S. higher education institutions, approximately half of all incoming freshmen require remedial services and 72% of all colleges offer remedial coursework to support underprepared students.¹⁷ It is axiomatic that increasing participation rates in higher education imply increasing proportions of students with associated risk factors.

Higher proportions of non-traditional aspiring engineering and science students evidence circumstances that have historically reduced their chances of successful college persistence and completion; hence, the origin of the terms “risk factors.” The largest portion of non-traditional students is first in their family to attend college, often referred to as “first-generation.”¹⁶ They tend to be “independent” insofar as they do not have parental, financial, or emotional support, and they are proportionally more likely to have dependents for whom they must provide support. They are also more likely to be single parents.¹⁶

The need to focus attention on non-traditional college students reinforces the argument to examine the performance of community colleges. These institutions enroll larger proportions of non-traditional students than do four year colleges and universities.⁶ According to NSF statistics, community colleges enroll 46% of science and engineering students, many of whom come from non-traditional backgrounds.⁴ Over the past three decades, students enrolling in community colleges characteristically had socio-demographic, familial, and academic characteristics that complicated going to college and mitigated chances for success. Community college students are largely non-traditional because they: (1) are typically older than the traditional undergraduate, (2) are more likely to come from underrepresented groups in STEM (~1.3 times as likely), (3) tend to be “independent” in that they do not have significant parental financial or emotional support (~1.5 times as likely), (4) often have dependents for whom they must provide support (~twice as likely), and (5) are more likely to be single parents themselves (~three times as likely).¹⁸ As elaborated upon below, there has been sparse research conducted on non-traditional college students, and in particular those who have career paths in engineering and science. It is however useful to note the important work of Rosenbaum and his colleagues who have studied such students.¹⁸ These researchers determined that in general, community colleges performed poorly in terms of providing out-of-class support to non-traditional students. Our study metrics, build upon the work of Deil-Amen, Rosenbaum and colleagues in addition to a pilot community college engineering and science study.

What must be better understood about community college support for students

Community colleges have taken on a “demand absorbing” role, which includes providing access to higher education for largely non-traditional students. Community colleges are two-year public institutions that have historically functioned as “open” institutions where a student with a high school degree, and in many instances without such a degree, has been able to attend. However, how a student progresses through his or her career and whether the individual completes a degree or transfers to a four-year institution has largely been understudied. At a minimum, community colleges in general have not faced closure or significant sanction because of low transfer rates. They serve students in particular programs that target engineering and science, however the impacts of these programs and the pedagogical supports that they provide students have rarely been studied. Accordingly, this is an area where further study is warranted.

Clear understanding of the role of particular pedagogical practices of community colleges in engineering and science are emergent, a state which is significantly improved via the present study. In our research, we build both upon our own STEM education work in community colleges and that of Rosenbaum, Deil-Amen, and colleagues, in which they explored differences between community colleges and occupational colleges, and their respective student support and non-classroom structures.²⁰ There are, of course, many issues that could be investigated because so little is known about community colleges especially as they cultivate students into engineering and other technologically focused workforces. Indeed, “gainful employment” is a topic that has gained much currency over the last few years. However, the focus of the research presented in this manuscript pertains exclusively to the experiences of students when they are in college—we are looking neither at pre-college experiences nor post-college employment activities. To be

certain, what takes place in college has a relationship to the information students are provided by college counselors and student affairs personnel, and the experiences that an engineering or science student has in college impacts the employment that will be found. However, the focus of the presented research is confined to the pedagogical practices engineering and science students encounter while studying with the intent of transferring to a four-year college or university for an engineering or science degree.

Importantly, we have chosen to focus on the engineering and science programs at community colleges for two reasons: (a) to provide a comparison not only at the school level but at academic program levels and also (b) many community colleges have no engineering program per say, but have science programs in which students major before transferring to university engineering programs, and, therefore, for generalizability of the research to other states and communities, the science majors at our participating community colleges have been included in our research sample.

We assert from review of the literature that there are major differences between community colleges and four-year colleges and universities. For example, transfer students complete their degrees at a much lower rate than those who attend a four-year college or university as freshman (55%).²¹ The research specific to STEM majors comparing community colleges to four-year institutions is limited; however, we know that 46% of students who major in STEM attended community colleges.⁶ There is sparse research about the pedagogical practices of community colleges, especially as they related to supporting students in engineering or science majors. That is, while we believe we understand the motivating factors of why community colleges behave differently from four-year traditional colleges and universities in their support of students and in particular in engineering and science, we seek to understand what their community college pedagogical practices are and how community colleges behave specific to those who choose engineering or science majors.

Examining creativity and propensity for innovation in community college engineering and science programs

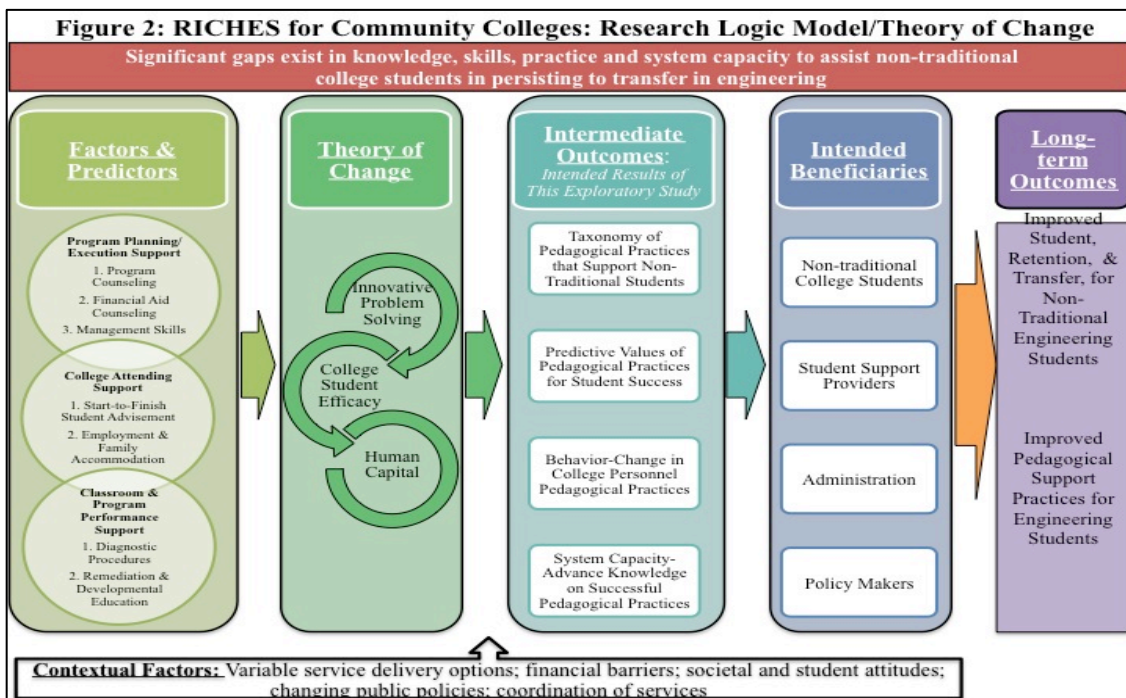
Our preliminary research on community colleges has indicated that students' propensity for innovative problem solving has a positive relationship with their college going persistence.²² Recent research in engineering education particularly has underscored this in university settings. Such research has indicated that while creativity and innovation are not synonymous, creativity is a necessary but insufficient condition for innovative thinking and eventual innovation in engineering workforce settings of diverse types.²³ While initially the bulk of research on creativity occurred in K-12 settings, most recently when creativity has been paired with innovation, the research has crept into business settings and now, in university settings.²⁴ Some, including Sheppard and colleagues, have suggested that particular pedagogical processes and student experiences have assisted in cultivating creativity, innovation and design orientation in students.²² Our research in engineering innovation and creativity has been a part of such effort.²³ In fact, our research has indicated that certain support services in universities including undergraduate research efforts, work on multidisciplinary teams, and mentorship have increased students' propensity for innovation.²⁵ Moreover our study on community colleges reveals that

students who had propensity toward innovative problem solving were more likely to transfer to four-year universities. This somewhat unexpected correlation inspired us to deliberately target this student characteristic for further research; and to dig deeply into the particular characteristics of community college pedagogical practices that successfully support non-traditional college students. What we are beginning to understand is the impact that community college students' creativity and innovative thinking has on transfer rates.²² Therefore, we intend to continue to examine this relationship further in this research.

Examining community college's pedagogical practices in engineering and science

Pedagogical practices for our research describes the wide array of institutional and student support practices that are designed with the intent of affecting student success in engineering and science. These practices range from how students are treated in the immediate post-enrollment process, to supportive mechanisms put in place to help individuals secure financial aid, to advisement and counseling differences in programs, to early identification and remediation of study skill deficiencies (e.g. in math and writing), to student-centered course schedules, to pro-active (institution-initiated) advice on transfer success, to undergraduate research experiences, to early internships and partnerships with industry. These are the sorts of factors over which institutions have control, have decided upon, and could change if they deemed necessary and especially if from our research we determined that particular support practices were more or less effective for engineering and science students. Our research intends to develop a comprehensive understanding of the support needs of non-traditional students in engineering and science and to tease out through our statistical models whether students with certain characteristics (e.g. creativity and propensity for innovation) persist to transfer at greater rates.

Research overview



The presented research is multidimensional and therefore follows a carefully crafted logic model (above) which includes a description of the pedagogical practices we are exploring, the theories we draw from, and intended research outcomes. Recognizing that students do not operate in college and university contexts irrespective of their affect and socio-demographic characteristics, this study operates from a combined human capital, developmental, and efficacy theoretical perspective. Human/social capital theory predicts that increases in knowledge and skills will translate to individual productivity.²⁸ This is particularly apparent in STEM fields where the knowledge, skills, and strategies that engineers and scientists need to complete their work rely on such capital. Student developmental theory focused on a person-environment perspective addresses interaction between conceptualizations of the college student and the college environment, viewing behavior as a social function of the person and the environment.²⁹ College-going efficacy perspective predicts that college students with efficacy will persist toward graduation at greater rates than non-efficacious students.^{30:31} Again, in engineering, college-going efficacy is critical because without it, not only are students less likely to persist to degree completion, even if they do persist, they may change from an engineering major to a humanities or liberal arts major. In our research, we determined that students' creative thinking and innovative problem solving interfaced with students' college going efficacy and capital, because the more effectively they can solve problems and navigate their way through the college landscape, the more likely they are able to persist to transfer to four-year schools. Figure 2 illustrates our theoretically grounded logic model (above), the nature of its interrelatedness, its multidimensionality, and ultimately, its connection to students persistence to degree in science and engineering. This model has informed our research design and provides grounding for our analytical choices and associated results. Accordingly, our research employs a mixed-method design using a randomization procedure in which students are randomly selected from each community college school site within the majors of engineering and science to participate, with randomization of selection occurring at the school site level within each targeted academic program. During the second through fourth years of our research, we have engaged in investigating factors associated with persistence, and transfer rates of students enrolled in science and engineering programs at the six participating community colleges with annual increases in numbers of participating schools. Specifically, in our research we compared and examined three categories of pedagogical support in engineering and science programs at the schools: (1) *classroom and program performance support*, (2) *college attendance support*, and (3) *program planning and execution support* and determined which student factors including socio-demographic factors, experiential factors, aspects of non-traditional status and students' creativity and propensity for innovative problem solving have related to student transfer to four-year schools.

Our multi-stage research has been structured such that each stage addresses one or more of the research questions presented in this manuscript. As previously described, this research takes place at six diverse urban community colleges in the western United States. Two of the six college have historically higher transfer rates and four have poorer transfer rates, so comparisons across the six institutions is important. The research is segmented into sequential stages: (1) Pedagogical Practices Taxonomy Collection and Instrument Refinement (one focus of this ASEE paper), (2) Instrument Validity and Reliability Re-Testing, and (3) Full Research Model Implementation (also in this ASEE paper). Specifically, in *stage 1*, we completed ascertainment

of the diverse set of pedagogical practices evident in the participating community colleges that are associated with engineering and science academic programs. This listing is described in the beginning of the results section of this paper, was presented in previous ASEE poster session papers, and has been used to inform a taxonomy of pedagogical practices that led to refinement and implementation of our college pedagogical practices inventory (CPPI, the instrument used in our described other STEM community college research). In *stage 2*, we tested the refined CPPI on a moderately robust student sampling (N~120). We engaged in validity and reliability retesting of the inventory using traditionally accepted statistical analyses. This instrument has been tested for validity and reliability in our previous work, however given that it was revised as a result of stage one of our research, it required retesting, (retested reliability coefficient: alpha value=.92). In *stage 3*, we began administration of the refined CPPI at the participating community colleges and explored the relationships among the dependent and explanatory/predictor variables using hierarchical linear modeling. This work is in progress and its third year of operation with a gradual introduction of new community colleges into the process to increase the study's sample size. Accordingly, we engaged in structural equation modeling (SEM).

Study Population: Two participant groups were recruited as study participants for this research: (1) non-traditional community college students in engineering and science (N= 3629 to date) and (2) community college student affairs personnel. Ten college administrators from each of the participating community colleges (N=41) were recruited for the purpose of obtaining information about their institutions' college pedagogical practices (as previous described) in engineering and science. Recruitment criteria for the student affairs personnel group were solely on the basis that they were student affairs personnel and that they had detailed information about their respective institution's pedagogical practices generally and specific to engineering and science programs.

A total of 3629 non-traditional community college engineering and science students have been recruited thus far for the study for stages 2 and 3 of the study with approximately 500-550 students from each of the community colleges. Although we have engaged in random selection of the students, prior to random selection, student affairs personnel at each college first identified a subset of non-traditional students using criteria from which we have randomly selected participants at each school site. We have enrollment in the first two years of community college as a necessary selection criterion for participant inclusion because we are exploring pedagogical practices as potential predictors of transfer persistence over two years and are aware that students take 2-4 years to transfer to universities from STEM programs. Necessarily, recruitment for the study will continue to the end of our multi-year project.

Instrumentation and Associated Data Collection Procedures: Two important instruments have been used to collect data for this research: (1) a student affairs personnel interview protocol which was used to collect descriptions and a detailed listing of the pedagogical practices provided by the participating community colleges, and (2) a multidimensional college pedagogical practices inventory (CPPI).

Student Affairs Personnel Interviews: Given that our research has an exploratory focus, as an initial step in this process, in preparation for refinement of our student college pedagogical

practice inventory (CPPI) that serves as our primary research instrument for two of the three stages of our study, we engaged in a series of intensive interviews with student affairs personnel at four community colleges. The purpose of these interviews was to obtain a detailed listing, comprehensive descriptions, and purpose and process information about the pedagogical practices at each community college with the intent of developing a complete and hierarchically focused, categorized pedagogical practice taxonomy that informed refinement of our CPPI and is in preparation for national dissemination.

This research builds upon the qualitative research of Rosenbaum, Deil-Amen, and Person⁷ in which they interviewed community and occupational college personnel and students. For our research forty-one interviews were conducted with approximately ten at each community college site during the first semester of our research. These data, along with a careful review of documents and websites available from each community college and applicable higher education literature as a comparison informed the refinement of the CPPI which was developed, and tested in our previously described STEM community college study.⁵

The Refined College Pedagogical Practice Inventory (CPPI-R): Refinement, testing, and use of the CPPI has been informed by measurement research of educational psychological researchers.³³ Specifically, the inventory was initially designed with the intent of enabling us to explore relationships among the dependent and independent variables associated with college pedagogical practices and to determine potentially predictive factors that relate to students' college going persistence and graduation. Content-wise, the CPPI-R contains the following subsections: (1) socio-demographic items that determine student background, personal structures, non-college and precollege experiences and student history, (2) items related to types and degree of pedagogical practice support offered to the students by their college and the frequency and usage of such pedagogical practices, (3) GPA indicating overall academic performance in college, and (4) items that measure critical aspects of student affective factors aligned to our theoretical approach (college going efficacy, human capital, creativity, innovation, and person-environment). We have adapted items from Lopez and Lent,³⁰ and Solberg, O'Brien, Villareal, Kennel, and Davis³¹ research instruments for our instrument. We included Solberg et.al. College Student Efficacy Index (CSEI) in it as well. The CSEI has an overall reliability coefficient of .87. We have included the Engineering and Science Creativity and Propensity for Innovation Index (ESCPII, alpha coefficient=.87), which includes Likert-type subscales and problem sets to measure these constructs, and has been used on four other engineering education research studies (at 25 + universities), as a means of measuring the community college students' creativity and propensity for innovative problem solving. The ESCPII is used as a predictive factor and then a dependent variable in our research to determine whether students' creativity and propensity for innovation predicts their college persistence or if the pedagogical practices support and cultivate creativity and propensity for innovation in community college engineering and science students. Structurally, the CPPI-R is a questionnaire in which students respond to close set questions associated with socio-demographics, type, duration, frequency, and usage of pedagogical practices categorized as the three sub-constructs of (1) *classroom and program performance support*, (2) *college attendance support*, and (3) *program planning and execution support*. These practices, (which we categorize to non-use, low use, moderate use and high use resulting from Likert-type scores) are loaded in to our model along with the scales (previously

described), Likert-type scales and problem sets to measure the described affective factors. This paper presents an update on our progress on this research (results presented below) and the remaining will occur in upcoming research.

Methodological approaches

As described above, three important, interrelated methodological approaches have been applied in the study.

Stage 1—Ascertainment of the Specific Pedagogical Practices and CPPI refinement: During the beginning of our research (the primary focus of a previous ASEE paper), we convened sets of expert panels at each community college site following the best practice identified by Wilson's item response theory (IRT) and instrument development.³² We interviewed forty-one college student affairs personnel (our "experts") at the first four study sites (~10+ per community college). As described previously, the purposes of the interviews were to obtain descriptive information about the diverse pedagogical practices and to create a comprehensive taxonomy of pedagogical practices from which to inform iterative revision of our college pedagogical practices inventory (CPPI), and essentially as a means of establishing large-scale content validity of the CPPI. Data from the interviews were audio recorded and transcribed in preparation for comprehensive qualitative analyses. Interview data were coded and thematically categorized using a constant, comparative method.³⁶ Special attention was paid to disconfirming evidence and outliers in data coding, as well as elements of frequency, extensiveness, and intensity within the data. Ideas or phenomena were first identified and flagged to generate a listing of internally consistent, discrete categories (open coding), followed by fractured and reassembled (axial coding) of categories by making connections between categories and subcategories to reflect emerging themes and patterns. Categories were integrated to form grounded theory (selective coding), to clarify concepts and to allow for interview interpretations, conclusions and taxonomy development. Frequency distribution of the coded and categorized data were obtained using a computerized qualitative analytical tool, Hyperresearch® version 3.5.2. The intent of this intensive qualitative analysis was to identify patterns, make comparisons, and contrast one transcript of data with another during the research taxonomy and the CPPI refinement.

Study findings and discussion

To our knowledge, prior to our research, there was no coherent (mutually exclusive and collectively exhaustive) taxonomy of pedagogical practices that may contribute to student success in science and engineering in community colleges because there has been sparse research on these efforts. Our intent in this part of our research was to explore this issue as a necessary component of our engineering education investigation. In the process of our initial work on this taxonomy, we determined that there are three broad categories of pedagogical practices on which we intend to build.

Stage 1 results

Results of this part of our research led us to the delineation and refinement of three categories of

pedagogical support: (1) *College attending support*, (2) *Program planning and execution support*, and (3) *Classroom and program performance support*. These three categories resulted from a study of a community college STEM academy and, therefore, the categories were refined as a function of the full scale of this research. Each category is described below.

(1) *College Attending Support*. For our first determined category of support, the type of pedagogical practice that pertains to interactions between the institution and students that are designed to facilitate college attendance in its broadest and most basic sense emerged. Specific examples of this practice include: providing information and counseling to current students on the alignment of program options and student interests and capabilities; counseling students on different avenues of financial aid; and providing students with task planning and management skills and information.²⁵ These practices provide the student with the ability to frame postsecondary education as a viable option in her or his life, and occur primarily very early in the student's program, perhaps even before formal classes have begun. Financial aid counseling illustrates this category of pedagogical practice. One of the perceived barriers faced by nontraditional students to higher education is the complexity of working through the federal financial aid application (FAFSA) and state financial assistance processes. According to Kantrowitz, 57% of Pell grant eligible students who attend community colleges obtain and retain their Pell funding; such an observation suggests that throughout one's academic career at a community college students receive some form of college attending support.²⁶ With that form of college attending support, institutions may be improving college attendance and completion.

(2) *Program Planning and Execution Support*. Our second determined category of pedagogical practice refers to services designed to facilitate student decision-making about program choice and accommodating program requirements within the constraints of employment and home obligations. In contrast to the first type of pedagogical practice, this category assumes the viability of some kind of postsecondary schooling, and instead addresses the unique characteristics of a student's interests, experiences, and capabilities in combination with specific program requirements and expectations in engineering and science. These pedagogical practices take place throughout the course of the student's progress through a program, as circumstances evolve and new requirements emerge. An illustration of this category of pedagogical practice involves the organization of student-related services and functions. Some of the community colleges that were a part of our research are staffed in such a way that their "student advisors" accompany students from the first point of inquiry at the community college all the way through to graduation—serving in effect as a continuous, known, reliable contact and source of "first-responder" support and guidance for all interactions between the student and the community college. Two of the STEM programs that we have studied for our research employed such pedagogical support through targeted advisement and mentorship, and found it effective in helping students to transfer to four-year colleges and universities. This is fundamentally different from the segmented departments of recruiting, admissions, advising, academic support, degree progress, bursar, and academic departments with which students must negotiate (often interacting with virtual strangers in one-off encounters) in other community colleges and, for that matter, universities.

(3) *Classroom and Program Performance Support*. The third type of pedagogical practice that

we noted in our research explicitly addresses student academic performance in the program, especially in individual classes but also more broadly to programs. This category of support differs from the other two categories in its explicit focus on monitoring (and remediating) individual student academic performance in as close to real time as possible. Examples of this type of pedagogical practice noted in our research range from systematic, periodic, frequent diagnostic procedures embedded within individual courses, to formal, separate offices designed to provide academic support to students who struggle with challenging class assignments. Common manifestations of this type of pedagogical practice are remedial education and so called “developmental education,” a practice commonly occurring in community colleges. Moss and Yeaton define remediation as a practice that is guided by learning theory and includes non-credit courses that address fundamental skills that students lack that is determined by college placement examinations.²⁷ Alternatively, per Moss and Yeaton, developmental education considers the life experiences of the students in addition to their entering skill level. Developmental education emphasizes the need for students to become independent and have self-regulation in their learning, rather than focusing on a deficit perspective of education, as is the case with remediation. As an illustration of this type of pedagogical practice, one community college in our sample provides a free non-credit course for those students whose academic skills require remediation. In a different community college in the sample, a community college pursues an “early warning” in-class system to supplement student diagnostic practices: if a student is absent for two consecutive class meetings, the instructor calls to inquire about any problems. Less remedial programmatic supports in this category that are often found in universities in STEM programs but less prevalent in the community colleges in our sample are early research experiences and internships. Our research has revealed that these practices were a part of a STEM academy at one of our participating community colleges. We determined that students who scored higher on engineering creativity and propensity for innovative thinking access these types of pedagogical practices at greater rates. We wished to determine whether the students’ experience in this category of pedagogical practices improved their propensity for innovation or if they chose such supports because of their propensity for innovation. Therefore, we explored these relationships further in the research. Results of our data analyses across themes are summarized in Table 1 by frequency distribution.

Table 1 Frequency Distribution of Themes in RICHES Stage 1 Research

Theme (type of pedagogical practice)	Frequency (%)	Example Quote (from interviews)
College Attending Support	72 (40.9)	“At our campus, we have career counselors that double as transfer counselors. They provide financial aid information and other information for students. They are not content specific.”
Program Planning & Execution Support	53 (30.1)	“The STEM advisors stick with our s STEM Academy students from the day they arrive until they transfer. They have rapport and relationships with the students. It really helps.”
College & Program	51 (29)	“We have a host of developmental courses. The

Performance Support		kids need them but they complain about not getting credit for them. Especially when they have to pay for books for the classes.”
	176 (100)	

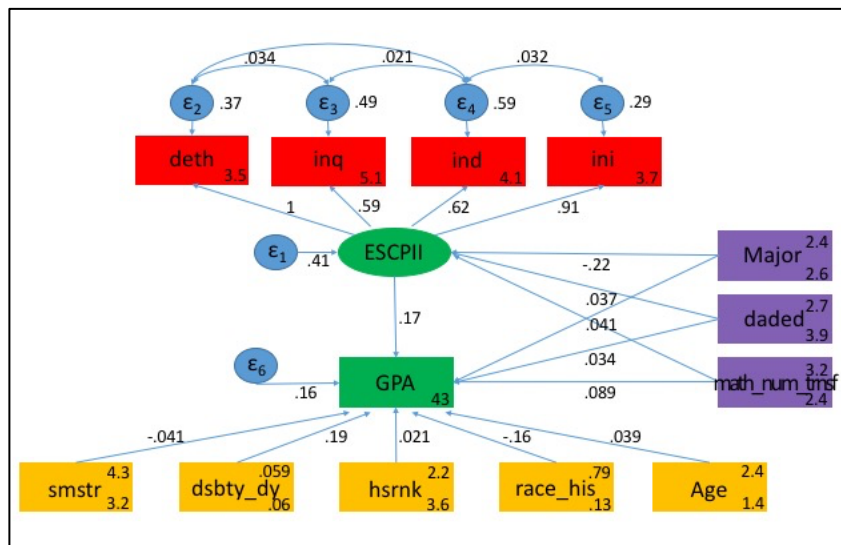
These data indicate that College Attending Support is most prevalent in the community colleges in our sample. Responses varied greatly, however by program and community college site.

Stage II results

In addition to completing the interview processes and analyses, we engaged in refinement of the CPPI (now CPPI-R) and data collection with a 3500+ student sample. We have conducted analyses of this group of community college students. Results are interesting and diverse.

Two structural equation models (SEMs) analyses were designed and utilized for our data analyses with community college student participant data. One model contains grade point average (as a proxy for achievement) as the outcome of interest and the second contains engineering and science creativity and propensity for innovation as the outcome of interest. Both diagrams are presented below as Figures 3 and 4.

Figure 3: SEM with GPA/Achievement as an Outcome Variable



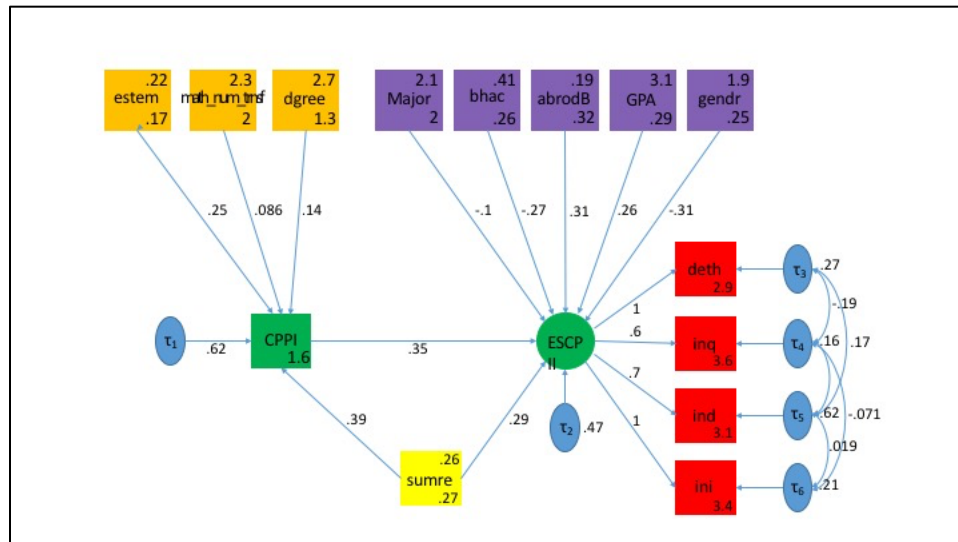


Figure 4: With Engineering Creativity and Propensity for Innovation as Outcome Variable

These two models indicate that use of pedagogical practices impact students' creativity and propensity for innovation and propensity for innovation impacts students' achievement (with GPA as a proxy.) Notably, background characteristics also have impacts on the two outcomes of interest in our research. These results are a work in progress and will be further explored in the future years of the research with an increasing sample.

Future research

Our results from our research are ongoing. Only through an in-depth, ongoing focused examination of the full range of pedagogical practices like that which will continue through the remainder of our research can we assert their fidelity and dimensionality with confidence. As such we will continue to recruit additional community colleges into our research to expand this research exploration. We understand that the institutional practices employed by any postsecondary institution interact with a complex array of student characteristics including students' propensity for innovation and circumstances that affect the likelihood of student success. This is an intent of our future work.

The following describes what we will do to complete our research in the final stage with additional community colleges added to our sample.

Stage 3—Exploring the Relationships of Student and Institutional Predictive Factors to Students' College-going Persistence Using Multinomial Hierarchical Linear Modeling: Hierarchical linear modeling will be used to explore the relationships amongst our identified variables and to determine explanatory and potentially predictive values of our independent variables on our dependent variables (college transfer persistence for round 1 of analyses and innovation for round 2). Our study follows a similar design and builds on the work of Desdemona-Cardoza, Raudenbush, and Byrk, and Rosenbaum and colleagues in which these researchers explored mediating factors that predict college attendance and persistence in students of various

types.^{38;39;40} Our CPPI will serve as the primary measurement for our research and will include the scales, (CSEI and ESCPII) as described above.

Acknowledgements

This research is being funded by the National Science Foundation (EEC- 1429229) entitled Research on Innovation and Creativity in Higher education in Engineering and Science (RICHES) for Community Colleges.

References

1. Ragusa, G. & Slaughter, J. B. (2015) Research on Innovation and Creativity in Higher Education in Engineering and Science for Community Colleges. *2015 American Society for Engineering Education Conference Proceedings*. Session AC-2015 14020. Seattle, WA.
2. Ragusa, G. & Slaughter, J. B. (2016) Research on Innovation and Creativity in Higher Education in Engineering and Science for Community Colleges: Student Strengths and Challenges. *2016 American Society for Engineering Education Conference Proceedings*. Session AC-2015 14020. New Orleans, LA.
3. PCAST STEM Undergraduate Education Working Group, S.J. Gates Jr., J. Handelsman, G.P. Lepage, & C. Mirkin, Co-chairs. (2012). *Engage to Excel: Producing one million additional college graduates with degrees in science, technology, engineering, and mathematics*. President's Council of Advisors on Science and Technology.
4. National Center for Education Statistics [NCES]. (2008). List of 2008 Digest Tables, Postsecondary Education, Table 186. Enrollment, staff, and degrees conferred in postsecondary institutions participating in Title IV programs, by type and control of institution, sex of student, type of staff, and type of degree: Fall 2005, fall 2006, and 2006–07. *Digest of Educational Statistics*. Retrieved from http://nces.ed.gov/programs/digest/2008menu_tables.asp
5. Ragusa, G., Levonisova, S., & Huang, S. (2013) "The Influence of Formal and Informal Pedagogical Practices on Non-traditional College Students' Achievement and Persistence in STEM Education." Association for the Study of Higher Education. St. Louis, MO.
6. Tierney, W. G. and Hentschke, G. (2007). *New players, different game: Understanding the rise of for-profit colleges and universities*. Baltimore, MD: Johns Hopkins University Press.
7. American Council of Community Colleges, 2014
8. Inside Higher Ed, 2013-2014
9. College Board, Trends in Community Colleges, 2013
10. Carnevale, A. P., & Desrochers, D. M. (2003). *Standards for what? The economic roots of K-16 reform* (pp. 27-30). Princeton, NJ: Educational Testing Service.
11. Lyall, K. C., & Sell, K. R. (2006). *The true genius of America at risk: Are we losing our public universities to de facto privatization? (ACE/Praeger series on higher education)*. Washington, DC: Praeger Publishers.
12. Tierney, W. G., (2008). Social mobility and stratification in the knowledge society. In Anthony Gladman (Ed.), *Europa world of learning 2009*. UK: Routledge.
13. National Center on Education and the Economy [NCEE]. (2007). *Tough choices or tough times: The new commission on skills of the American workforce*. Jossey-Bass.
14. Organisation for Economic Co-operation and Development [OECD]. (2006). *Education at a Glance: OECD Indicators*, Paris, OECD.
15. Gladioux, L. & Perna, L. (2005). *Borrowers who drop out: A neglected aspect of the college student loan trend*. The National Center for Public Policy and Higher Education (Report #05-2). Retrieved from <http://www.highereducation.org/reports/borrowing/index.shtml>
16. National Center for Education Statistics [NCES]. (2008). List of 2008 Digest Tables, Postsecondary Education, Table 192. Total fall enrollment in degree-granting institutions, by control and type of institution, age, and attendance status of student: 2007. *Digest of Educational Statistics*. Retrieved from http://nces.ed.gov/programs/digest/2008menu_tables.asp
17. National Center for Education Statistics [NCES]. (2008). List of 2008 Digest Tables, Postsecondary Education, Table 328. Percentage of degree-granting institutions offering remedial services, by type and control of institution: 1989–90 through 2007–08. *Digest of Educational Statistics*. Retrieved from http://nces.ed.gov/programs/digest/2008menu_tables.asp
18. Ruch, R. S. (2001). *Higher ed, inc.: The rise of the for-profit university*. Baltimore, MD: The Johns Hopkins University Press.
19. Deil-Amen & Rosenbaum, 2003; Person & Rosenbaum, 2006; Person, Rosenbaum & Deil-Amen, 2006
20. National Center for Education Statistics, Integrated Postsecondary Education Data System (IPEDS). (2007), *Enrollment in postsecondary Institutions, fall 2007; Graduation rates, 2001 & 2004 Cohorts; and Financial statistics, fiscal year 2007*. U.S. Department of Education: Washington, DC.
21. Rosenbaum, Deil-Amen, and colleagues; 2003,2005,2007
22. Torrance, E. P. (1981). Predicting the creativity of elementary school children (1958 80) and the teacher who "made a difference." *Gifted Child Quarterly*, 25, 55-62.

23. Abedi, J. (2007). A latent-variable modeling approach to assessing reliability and validity of a creativity instrument. *Creativity Research Journal*, 24(3).
24. Sheppard, S.D., Macatangay, K., Colby, A., & Sullivan, W. M. (2008) *Educating engineers: Designing for the future of the field*. San Francisco: Jossey-Bass.
25. Ragusa, G. (2011) Engineering Creativity and Propensity for Innovative Thinking In Undergraduate and Graduate Students. *Conference Proceedings: Annual Meeting American Society of Engineering Educators*, Vancouver, Canada. 2011
26. Kantrowitz, M. (2012) Who graduates from college with 6 figure debt? Student Aid Policy Analysis. Fastweb.
27. Moss, B. G. & Yeaton, W. H. (2006). Shaping policies related to developmental education: An evaluation using the regression-discontinuity design. *Educational Evaluation and Policy Analysis*, 28(3), 215-229.
28. Becker, G. (1967). *Human capital and the personal distribution of income: An analytical approach*. Ann Arbor: University of Michigan Press.
29. Feldman, K. A., Smart, J. C., & Ethington, C.A. (1999). Major field and person-environment fit: Using Holland's Theory to study change and stability of college students. *Journal of Higher Education*, 70(6) 642-69.
30. Lopez, F.G., & Lent, R.W. (1991). Efficacy-based predictors of relationship adjustment and persistence among college students. *Journal of College Student Development*, 32, 223-229.
31. Solberg, V.C., O'Brien, K., Villareal, P., Kennel, R. & Davis, B. (1993). Self-efficacy and Hispanic college students: Validation of the college self-efficacy instrument. *Hispanic Journal of Behavioral Sciences*, 15(1), 80-95.
32. Wilson, M. R. (2011). *Constructing Measures*. New Jersey: Lawrence Erlbaum.
33. Cohen, J. (1989). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Erlbaum.
34. Murphy, K.R. and Myors, B. (2003). *Statistical power analysis: A simple and general model for traditional and modern hypothesis tests* (2nd ed.). Lawrence Erlbaum Associates, Inc.
35. Lincoln, Y., & Guba, E. (1985). *Naturalistic inquiry*. New York: Sage.
36. DeWitz, S. J., & Walsh, W. B. (2002). Self-efficacy and college student satisfaction. *Journal of Career Assessment*, 10(3), 315-326.
37. Beatty, P. (2004). The dynamics of cognitive interviewing. In S. Presser, J. M. Rothger, M.P. Couper, J. T. Lessler, E. Martin, & E. Singer (Eds.), *Methods for testing and evaluative survey questionnaire* (pp. 45-66). Hoboken: Wiley Publication.
38. Rosenbaum, P., & Rubin, D. (1983). The central role of the propensity score in observational studies for causal effects. *Biometrika*, 17, 41-55.
39. Raudenbush, S. W., & Bryk, A. S. (2002). *Hierarchical linear models: Applications and data analysis methods*. Thousand Oaks, CA: Sage.
40. Raudenbush, S., & Willms. (1995). The estimation of school effects. *Journal of Educational and Behavioral Statistics*, 20(4), 307-335.