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Research on Innovation and Creativity in Higher Education in Engineering and Science for Community Colleges: Student Strengths and Challenges

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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 persist to degree completion. Accordingly, this research seeks to examine a sample of non-traditional college students enrolled in science and engineering programs in four 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 their propensity for innovation and creative problem solving affects such choices and persistence. The study 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 are: (1) to explore the pedagogical practices used to support non-traditional students in community colleges to inform persistence, (2) to understand whether such practices are effective in offering non-traditional students a program that enables them to stay in engineering and science majors and to transfer to a four year college or university, and (3) to determine if students' propensity for innovative problem solving influences use of pedagogical practices and ultimately, transfer persistence. 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 4-year universities?

This research studies an area and group of students that have been historically understudied, community college students in engineering and science. It builds upon the researchers' current studies of STEM pathways and students' propensity for innovation, both of which are research areas recognized as areas that engineering education must cultivate in students. The research also provides rigorous empirical research on students who have been traditionally underrepresented in higher education research, thereby advancing the knowledge to higher education research communities.

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.[1] According to national statistics, the largest groups of underrepresented minority students in engineering and science attend the US public higher education institutions and in particular the community colleges.[2] 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 persist to degree completion. The present research underscores the importance of innovative problem solving for students to persist in engineering majors.[3] Accordingly, this engineering education seeks to examine a sample of non-traditional college students enrolled in science and engineering programs in four 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 their propensity for innovation and creative problem solving affects such choices and persistence. This paper presents on the first and second year of a three-stage 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 stay 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 the study's research team conducted that focused on one community college, student persistence and propensity for innovative problem solving, and extends this research to a multidimensional, comparative study of four 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 4-year universities?

The first two years of this research focuses upon the first four questions from the list above.

Critical factors affecting community college students

Based on a review of the literature and the authors' research over the last decade, four "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; (3) the leadership of the United States in postsecondary education provision is eroding; and (4) future increases in enrollments will be composed significantly of "non-traditional" students.[4] Each point is discussed briefly below.

Ongoing growth of community colleges

While some of the 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 (CCs) serve more first generation college students, those who are traditionally underrepresented in science technology, engineering and math (STEM) and others with financial needs. According to the American Council of Community Colleges, full time enrollment in CCs remain stable, with approximately 8,000,000 students enrolled full time, yet part time enrollment is on the rise.[5] 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 set national trends.

Community colleges enroll some of the neediest students nationally with 34% of all Pell Grant recipients during the first quarter of 2012 enrolled in community colleges, a share that increased by 3% compared to the same period last year.[6] Of all degrees completed by those who initiated their experiences in community colleges, only 12% of all degrees completed were in STEM fields compared to 34% in social sciences and humanities fields.[6]

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.[7] 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.[8] The earnings advantage of bachelor's degree holders over high school graduates increased by about 36% between 1979 and 2001, reaching 76%.[8]

As the United States gradually evolves from a national 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.[9] 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.

Erosion of leadership in United States postsecondary education

While the US 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.[10] As framed by the New Commission on The Skills of the American Workforce, America's pipeline is "leaky."[11] For every 100 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.[10] 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.[11] 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.[12]

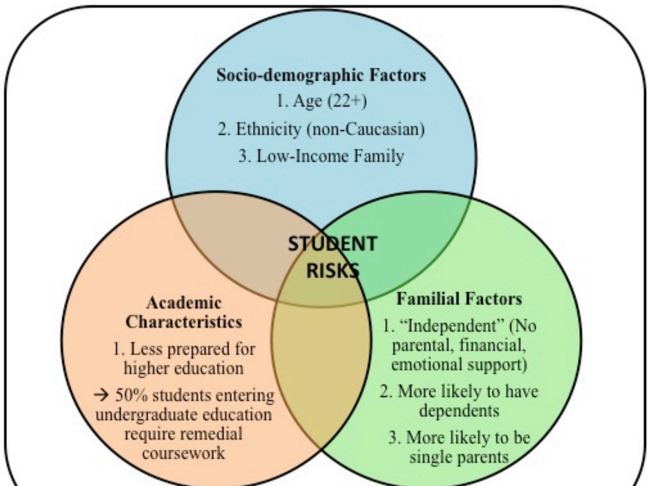


Figure 1: Profile of Non-traditional Students in Colleges

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 collection of student characteristics that depart from the stereotypical characteristics of the historic college undergraduate 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.[13] 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 in particular in STEM. Consider age as an illustration of this profile. "Undereducated" adult students constitute a large and growing proportion of the US workforce. Of the more than 200 million adults in the US, 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.[9] 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 US 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.[7] Figure 1 provides an illustration of the complexities of US 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 to enroll in postsecondary programs continues to increase, the risk factors and deficits in academic preparation of new cohorts of students are increasing.[14] This presents a significant burden to postsecondary institutions that admit "under-qualified" students, as is the case with community colleges. National 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.[15] 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 going and completion; hence, the origin of the terms "risk factors." The largest portion of non-traditional students is first-generation.[14] 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.[14]

The need to focus attention on non-traditional students reinforces the argument to examine the performance of CCs. These institutions enroll larger proportions of non-traditional students than do four year colleges and universities.[4] According to NSF statistics, CCs enroll 46% of science and engineering students, many of whom come from non-traditional backgrounds.[2] Over the past three decades, students enrolling in CCs characteristically had socio-demographic, familial, and academic characteristics that complicated going to college and mitigated chances for success. CC 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).[16]

As we elaborate below, there has been very little research conducted on the non-traditional students, and in particular those who have career paths in engineering and science, but it is useful to note the important work of Rosenbaum and his colleagues who studied such students.[16] These scholars 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 and 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. CCs 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, CCs 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 CCs in engineering and science are preliminary, a state which would significantly improve via this 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.[18] There are, of course, many issues that could be investigated because so little is known about CCs 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 this research pertains exclusively to the experiences of students when they are students—we are looking neither at pre-college experiences nor post-college employment activities. To be sure, what takes place in college has a relationship to the information students are provided by college counselors and student affairs staff, and the experiences that an engineering or science student has in college impacts the sorts of 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 in an engineering or science degree.

Importantly, we have chosen to focus on the engineering and science programs at CCs for two reasons: (a) to provide a comparison not only at the school level but at academic program levels and also (b) many CCs 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.

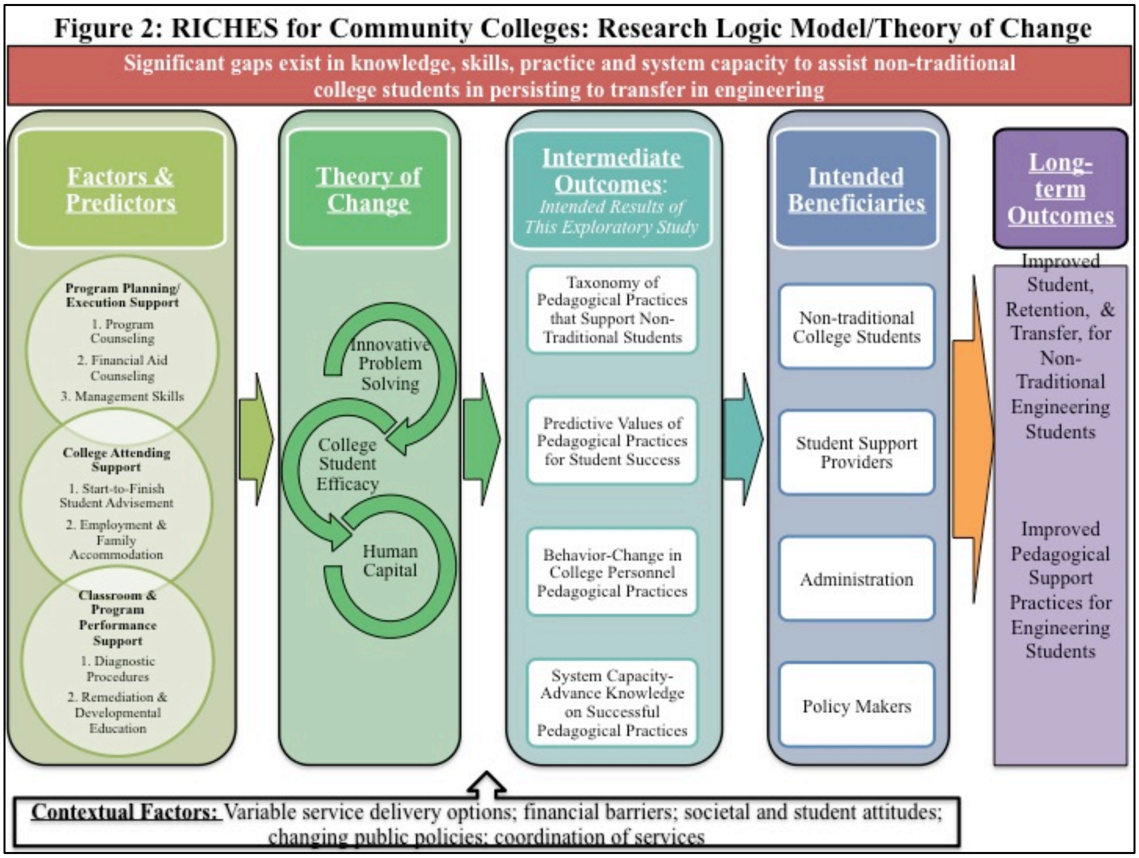
We assert from review of the literature that there are major differences between community colleges and 4-year colleges and universities. For example, transfer students complete their degrees at a much lower rate than those who attend a four-year college or university as freshman (55%).[19] The research specific to STEM majors comparing CCs to 4-year institutions is limited; however, we know that 46% of students who major in STEM attended CC.[4] And there is next to no research about the pedagogical practices of CCs, especially as they related to supporting students in engineering or science majors. That is, while we believe we understand the motivating factors of why CCs 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 CC pedagogical practices are and how CC's behave specific to those who choose engineering or science majors.

Examining creativity and propensity for innovative thinking in community college engineering and science

Our preliminary research on CCs has indicated that students' propensity for innovative problem solving has a positive relationship with their college going persistence.[20] 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.[21] 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.[22] 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.[20] Our research in engineering innovation and creativity has been a part of such effort.[21] 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.[23] Moreover our study in CCs revealed 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 on the particular characteristics of community college pedagogical practices that support non-traditional college students. What we have yet to determine is whether students' creativity and innovative thinking influenced transfer rates or vice versa in our research.[20] Therefore, we intend to examine this relationship further in this study over the next three years.

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 appear to and 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 on 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 hope long term is to develop a comprehensive understanding of the support needs of nontraditional 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 which includes a description of the pedagogical practices we explore, 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-demographics, this study operates from a combined human capital, developmental, and efficacy theory of change perspective. Human/social capital theory predicts that increases in knowledge and skills will translate to individual productivity.[26] 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.[27] College-going efficacy perspective predicts that college students with efficacy will persist toward graduation at greater rates than non-efficacious students.[28;29] Again, in engineering, college-going efficacy is critical because without it, not only are students less likely to persist, even if they do persist, they may change from an engineering major to a humanities or liberal arts major. In our preliminary research, we found 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 status. Figure 2 illustrates our theoretically grounded logic model, the nature of its interrelatedness, its multidimensionality, and ultimately, its connection to persistence. This model informs and guides our research design and provides grounding for our analytical choices and associated results. The research plan that follows articulates this.

Over the course of three years, our research employs a mixed-method design using a randomization procedure in which in which students are randomly selected from each CC 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 and third year of our research, we investigate factors associated with persistence, and transfer rates of students enrolled in science and engineering programs at four CCs (see attached letters of commitment). Specifically, we compare and examine three categories of pedagogical support in engineering and science programs at these schools: (1) *classroom and program performance support, (2) college attendance support, and (3) program planning and execution support* and determine which student factors including socio-demographic factors, experiential factors, aspects of non-traditional status and students' creativity and propensity for innovative problem solving relate to student transfer.

As previously described, during this time, the research addresses five 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 4-year universities?

Our research has three stages (described below) and has been structured so that each stage addresses one or more of the research questions. This paper describes the first and second stages of this research. As previously described, this research takes place at four diverse urban community colleges in the western United States. Two of the four college have historically higher transfer rates and two have poorer transfer rates, so comparisons across the four institutions is important. The research is segmented into three sequential stages: (1) Pedagogical Practices Taxonomy Collection and Instrument Refinement (the focus of this ASEE paper), (2) Instrument Validity and Reliability Re-Testing, and (3) Full Research Model Implementation. Specifically, in ***stage 1***, and for this paper we have completed ascertainment of the diverse set of pedagogical practices evident in the CCs that are associated with engineering and science academic programs. This listing is described in the beginning of the results section of this paper 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 CC research). In ***stage 2***, we tested the refined CPPI on a moderately robust student sampling (N~120). We have 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 may be 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 preliminarily explored the relationships among the dependent and explanatory/predictor variables using hierarchical linear modeling. This work is in progress. Accordingly, we engaged in structural equation modeling (SEM) in advance a full scale HLM (the final portion of our research.)

Study Population: Two participant groups were (will be for future study stages) recruited as study participants for this research: (1) non-traditional community college students in engineering and science (N= 1647 to date) and (2) community college student affairs personnel. Ten college administrators from each of the participating community colleges (N=40) 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 that they are student affairs personnel and that they had detailed information about their institution's pedagogical practices generally and specific to engineering and science programs.

Approximately 2,000 non-traditional community college engineering and science students are recruited for the study for stages 2 and 3 of the study with the goal of recruiting 500 students from each of the community colleges (1647 have been recruited to date). 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 three-year project.

Instrumentation and Associated Data Collection Procedures: Two important instruments have been used to collect data for this exploratory study: (1) a student affairs personnel interview protocol to be 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/data collection tool for two of the three stages of our CC study, we engaged in a series of intensive interviews with student affairs personnel at each of the 4 participating CCs. The purpose of these interviews was to obtain a detailed listing, comprehensive descriptions, and purpose and process information about the pedagogical practices at each CC with the goal of developing a complete and hierarchically focused, categorized pedagogical practice taxonomy that informed refinement of our CPPI (described below) and will be disseminated nationally.

This research builds upon the qualitative research of Rosenbaum, Deil-Amen, and Person[5] in which they interviewed CC and occupational college personnel and students in both educational venues. Forty-one interviews were conducted with 10+ at each CC site during the first semester of our research. These data, along with a careful review of documents and websites available from each CC 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.[3]

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.[31] 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,[28] and Solberg, O'Brien, Villareal, Kennel, and Davis[29] research instruments. We include Solberg et.al. College Student Efficacy Index (CSEI). The CSEI has an overall reliability coefficient of .87. We have included the Engineering Creativity and Propensity for Innovation Index (ECPII, 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 20 + universities), as a means of measuring the CC students' creativity and propensity for innovative problem solving. The ECPII is used as a predictive factor and then a dependent variable to determine whether creativity and propensity for innovation predicts 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, Likert-type scales and problem sets to measure the described affective factors. Some of this is reported on via our preliminary data collection (results presented below) and the remaining occurs in the remaining year of our funded research.

Methodological approaches

As described above, three important, interrelated methodological approaches have been (and will continue to be) applied in the study.

Stage 1—Ascertainment of the Specific Pedagogical Practices and CPPI refinement: During stage 1 of our research (the focus of the present ASEE paper), we convened sets of expert panels at each CC site following the best practice identified by Wilson's item response theory (IRT) and instrument development.[30] We interviewed 41 college student affairs personnel (our "experts") at our study sites (10+ per CC). As described previously, the purposes of the interviews are 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 our CPPI. Data from the interviews were audio recorded and transcribed in preparation for comprehensive qualitative analyses. Interview data was coded and thematically categorized using a constant, comparative method.[34] 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, Hyperrresearch® 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 our taxonomy and CPPI refinement.

First 2 years study findings and discussion

To our knowledge, there is no coherent (mutually exclusive and collectively exhaustive) taxonomy of pedagogical practices that may contribute to student success in science and engineering in CCs because there has been sparse research on these efforts. Our intent in this study is 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. To fuel this effort, we conducted a study at a large minority serving CC in STEM to determine a baseline of the kinds of pedagogical supports that are provided.

Stage 1 results

Results of this part of our research led us to the delineation and refining 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. This type of pedagogical practice pertains to interactions between the institution and students that are designed to facilitate college attendance in its broadest and most basic sense. 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.[23] 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 CCs obtain and retain their Pell funding; such an observation suggests that throughout one's academic career at an CC students receive some form of college attending support.[24] With that form of college attending support, institutions may be improving college attendance and completion—or not.

(2) Program Planning and Execution Support. A second 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 can 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 CCs are staffed in such a way that their "student advisors" accompany students from the first point of inquiry at the CC 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 CC. 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 4-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 many CCs and, for that matter, universities.

(3) <u>Classroom and Program Performance Support.</u> The third type of pedagogical practice 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 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.[25] 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 CC provides a free non-credit course for those students whose academic skills require remediation. In a different example of this type, one CC 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 CCs are early research experiences and internships. The initial research in which we have engaged has revealed that these practices were a part of the STEM academy. In related research, we found that students who scored higher on engineering creativity and propensity for innovative thinking access these types of pedagogical practices at greater rates. We are not yet certain whether the students' experience in these pedagogical practices improved their propensity for innovation or if they chose such supports because of their propensity for innovation. Therefore, we wish to explore these relationships further in the remaining years of this funded 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 Performance Support	51 (29)	"We have a host of developmental courses. The 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 preliminary that College Attending Support is prevalent in the program. Responses varied greatly 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 moderate sample of students (recruitment is still in process.) We also conducted preliminary analyses of the first group of community college students. Results are interesting and diverse.

Two structural equation models (SEMs) analyses were conducted with 1 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 diagrams are presented below as Figures 3 and 4.

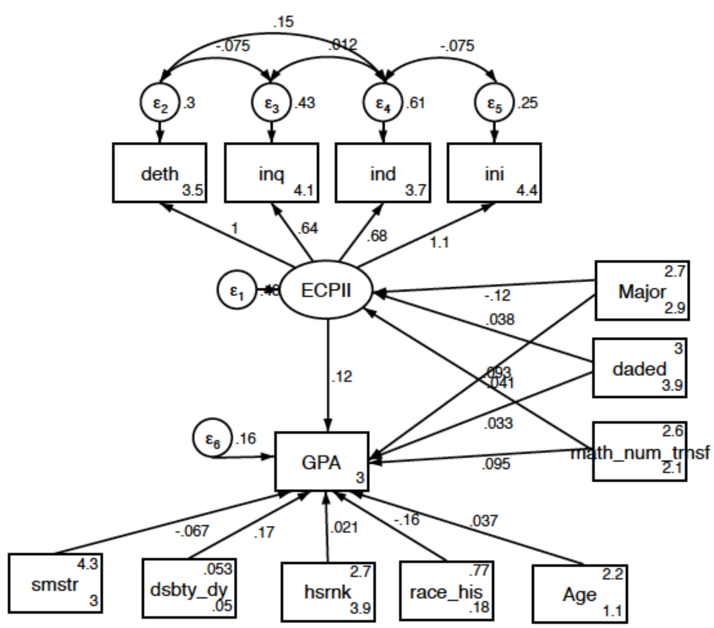


Figure 3: SEM with GPA/Achievement as an Outcome Variable

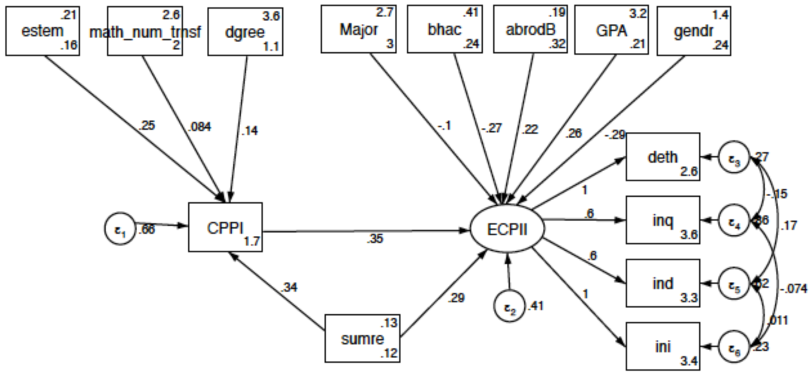


Figure 4: With Engineering Creativity and Propensity for Innovation as Outcome Variable

These two preliminary 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. These results are preliminary (as a work in progress) and will be further explored in the final year of the research.

Future research

Our three categories of pedagogical practices are some what preliminary and result from our first two years of research. Only through an in-depth, ongoing focused examination of the full range of pedagogical practices like that which is proposed through the remaining years of our research can we assert their fidelity and dimensionality with confidence. We do know 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 year/ final stage.

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 ECPII) as described above.

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