Leveraging Pedagogical Practices in the Classroom to Promote Aspirations for a Research Career

Ashlee Wilkins, Sylvia Hurtado & Tanya Figueroa

University of California, Los Angeles

Association for Study of Higher Education (ASHE)

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Introduction

It is a national priority to increase the number of STEM researchers for technological advancement and scientific innovation (PCAST, 2012). Fortunately, freshman students entering four-year colleges and universities are more interested in pursuing a STEM degree now than ever before (Eagan, K., Hurtado, S., Figueroa, T. & Hughes, B., in press)). However, only 3.3% state that they are interested in pursuing a research career at college entry (Eagan, Stolzenberg, Ramirez, Suchard & Hurtado, 2014). Given that introductory STEM classrooms are typically the first formal context to which students are exposed within the college setting, they represent a great vehicle by which to pique students' interest in STEM-related research careers. Previous research shows that the classroom environment shapes intellectual abilities, investigative competencies, academic success, and professional aspirations (Cabrera et al., 2002).

STEM classrooms that provide intellectual engagement are more likely to retain talented students (Johnson, 2007), which provides for a greater pool of individuals who can potentially enter careers as STEM researchers. Unfortunately in route to a STEM degree, students confront introductory STEM courses that are typically characterized by extremely large class sizes and the reliance on lecture-based pedagogical practices that result in passive learning (Perna et al., 2010). Furthermore, culturally relevant pedagogy embedded within the curriculum and an application of course concepts to the real world are typically absent from STEM introductory courses (Davis & Finelli, 2007; Jarosz, 2003). The typical STEM classroom, as described above, tends to have an adverse impact on all students, but especially those who come from underrepresented racial minority (URM) backgrounds—including Black, Latino, and American Indian students (Johnson, 2007, Perna et al., 2010). This is especially concerning given the necessity for more diverse perspectives in the STEM workforce (Blickenstaff, 2005).

Since faculty within STEM classrooms are typically the first point of introduction to STEM research careers, they are uniquely positioned to shape students' research interests through structured experiences in the classroom, such as the assignment of research intensive projects (Seymour et. al, 2004). Furthermore, faculty can facilitate the academic success of URMs in the classroom by using collaborative pedagogical approaches (Cabrera et al., 2002; Johnson, 2007, Perna et al., 2010). Few studies, however, have examined whether pedagogical practices in introductory STEM courses contribute to or detract from entering college students' baseline aspirations for a research career. This type of research is needed so that STEM educators can identify and later use evidence-based practices that promote student interest in STEM careers and research, especially among URM students. Research findings can also motivate institutions to collect classroom data so that they can identify the efficacy of pedagogical practices and classroom environments that bolster URM student interest in STEM research careers.

This purpose of this study is to identify the factors that increase the likelihood of entering college students' plans to pursue a STEM research careers, comparing URM and majority students. We use longitudinal data from 3,205 students across 76 introductory STEM courses at 15 institutions to investigate the unique impact practices utilized in the STEM introductory classroom have on the likelihood that students report they aspire to pursue a career that includes conducting scientific research. Specifically, this study seeks to answer the following research questions:

1. What pedagogical practices utilized in introductory STEM courses are conducive to cultivating students' aspirations towards careers in research?

2. How does the effect of these practices differ for Underrepresented Racial Minority (URM) students and non-URM students?
3. How do experiences within STEM introductory classes differ for URMs and non-URM students?

Literature Review

Introductory Courses

Introductory courses are typically referred to as “gatekeepers” because they symbolize the initial courses in a sequence of classes where knowledge is transformed into a cumulative experience (Freeman, Haak, & Wenderoth, 2011). In theory, achievement in introductory courses is defined as a function of mastering content knowledge and scientific thinking dispositions (Conley, 2005). However, in practice, undergraduate introductory STEM courses generally emphasize the acquisition of content knowledge, rather than the development of skills associated with critical thinking and scientific literacy (Williams, Papierno, Makel, & Ceci, 2004). Consequently, introductory STEM courses have fairly high failure and dropout rates (Seymour & Hewitt, 1997). The inability to pass gatekeeper courses often leads to challenges in subsequent classes and may compel students to withdraw from STEM majors and abandon aspirations to pursue a research career in STEM (Labov, 2004).

In gateway STEM classes, lectures are less likely to require students to critically think about the course content and may not offer the stimulation needed to intellectually engage students in learning science and mathematics (Gasiewski, Eagan, Garcia, Hurtado & Chang, 2012). On the other hand, active participation in the classroom setting allows students to cultivate the habits of mind that that serve as the foundational elements of science and stimulates an inquisitive mind. Unfortunately, many introductory classes strictly utilize lecture as the mode of teaching; this practice does not support active participation (Handelsman et al., 2004). Disengaging gateway courses can lead students to feel uninterested and disconnected from science putting talented students at risk of deciding to discontinue their STEM education, precluding them from entering STEM research careers (Seymour & Hewitt, 1997).

Facilitating Research Aspirations Via Pedagogy

Pedagogical strategies that stimulate engagement within the learning environments bolster achievement and afford students with opportunities to critically process scientific concepts and their applications—which inevitably support the acquisition of higher-order intellectual skills (Allen, Duch, & Groh, 1996; Sagan, 1996) and may increase the likelihood that students aspire for a STEM research careers. Active learning may be effective as it creates a space where students can freely share multiple perspectives on a problem, which requires students to analyze numerous sources of evidence before determining a specific resolution to the issue (Smith, Sheppard, Johnson, and Johnson, 2005). Encouraging student participation in the classroom, incorporating students' ideas in discussion, and facilitating student interactions among each other (Berrett, 2012; Terenzini, Theophilides, & Lorang, 1984), facilitate higher-order critical thinking skills which are essential for STEM research (Haak, HilleRisLambers, Pitre, & Freeman, 2011). Other active learning exercises that promote critical thinking include involvement in research projects (Tsui, 2002), participation in academic support programs (Summers & Hrabowski, 2006), and taking essay exams (Astin, 1993).

The feel of the classroom also matters with hostile or competitive environments having an adverse effect on students' achievement, whereas positive, supportive, and collaborative learning spaces enrich student learning (Berrett, 2012). Prenzel, Kramer, and Dreschel (2002) outline six conditions that are unique to collaborative classroom environments: quality of instruction; relevance of content; social relatedness; teacher‘s interest; support of autonomy; and support of competence. Classrooms that offer relevant content expose students to opportunities for real-world application of content knowledge. Further, quality instructors can communicate information to students in a coherent way and can accommodate a multiplicity of learning styles. Interested instructors display their commitment to student learning and an ethic of care in respect to students' academic difficulties. Classrooms that infuse student-to-student engagement activities promote collegiality and cooperation. Faculty can support the development of students' academic competencies by providing personalized constructive feedback on assignments. Finally, classroom environments that foster the process of inquiry exposes students to an intensive exploration in problem solving, which lends to multifaceted approaches for reaching resolutions and conclusions. Moreover, these skills are highly valued within STEM research careers. The ability to think and act like a STEM researcher requires that students move from thinking about abstract concepts to the concrete application of those very same concepts. More specifically, thinking like a STEM researcher involves identifying salient issues, asking questions, weighing evidence to make appropriate decisions, and finding avenues to make scientific findings relevant and consumable for society at large (Williams, Papierno, Makel, & Ceci, 2004).

Theoretical Framework

Social Cognitive Career Theory (SCCT) (Lent, Brown, & Hackett, 1994), examines the interplay of five dimensions theorized to be important to the development of career interests.

These dimensions include: 1) personal inputs such as predispositions, gender and race, 2) family background, 3) learning experiences including those occurring in the classroom environment, 4) expectations for outcomes, and 5) self-efficacy or one's perception of their abilities. Applied to this study, SCCT can help untangle the complex process of how people develop their career interests.

Following SCCT, students are expected to be more likely to articulate interests in a career field or domain when they have positive perceptions about their performance and abilities. Students who have a strong sense of STEM identity and who are able to see themselves as one day being STEM professionals are therefore expected to have an increased likelihood of having STEM-related career goals. Finally, SCCT highlights the value of identifying contextual supports and barriers (Lent et al., 1994). Supports refer to factors within the learning environment that bolster success associated to pursuing a STEM related career (e.g., having positive interactions with faculty and peers, and classroom practices that encourage active learning). Conversely, barriers relate to pivotal events within the undergraduate experience that undermine interests in pursuing a STEM career in research (e.g., working full-time during college, a competitive classroom environment, etc.). An application of SCCT to this study is useful in that it demonstrates that pedagogical practices in STEM introductory classes likely matter in promoting students' interest in a research career, particularly among URM students.

Modes of Inquiry and Methods:

Data Source and Sample

To investigate the factors within introductory STEM courses that shape students' aspirations to pursue research careers in STEM, we draw data from three surveys distributed in STEM introductory classrooms. The first is the 2010 STEM Student pre-Questionnaire distributed by the Higher Education Research Institute at UCLA, which was administered at the beginning of an academic term and collected information on students' self-rated academic and science abilities, the frequency they articulate and apply science concepts, and demographic information. The follow-up 2010 STEM Student Post-Questionnaire was distributed at the end of the same term and repeated many of the questions from the first survey while also including a number of items related to students' experiences within the introductory course. Lastly, faculty who taught these introductory STEM courses completed an online instructor survey at the end of the course, and this instrument included items related to the pedagogical techniques they used in the course, their perception of student learning, and their priorities for undergraduate education. In all, 3,205 students across 76 introductory STEM classrooms at 15 institutions responded to both student surveys. The longitudinal response rate was 42.1% and an weight was computed based on students' probability of responding to both surveys to adjust for nonresponse bias. This weight adjusts for non-reponse bias that allows for greater representation of the post-survey results of the sample of students who took the initial pre-survey.

Variables

Primary dependent variable. This study identifies pedagogical practices in introductory STEM courses that are conducive to cultivating students' aspirations towards careers in research. The primary outcome is a one-item construct indicating students' aspirations for pursuing a career that includes conducting STEM research. The dependent variable was measured at the end of the academic term and indicates the likelihood a student self-reported that they would enter a STEM research career. The dependent variable is ordinal and measured on a four-point Likert scale (1= "very unlikely" to 4="very likely").

Endogenous variables. Aside from the dependent outcome, there were four additional hypothesized endogenous variables in the model. The construct *STEM efficacy* measures students' perceptions of their STEM-related abilities at the beginning of the academic term (as reported on the pre-survey). This factor is composed of three self-rated items (e.g. seeing connections between different areas of science and math, relate concepts to real world, and make predictions based on existing knowledge), each of which asks students to rate themselves on a five-point Likert scale (1="Lowest 10%" to 5="Highest 10%"). In investigating students' *outcome expectations*, a single item indicated students' initial intentions to pursue a research career in STEM (as captured on the pre-survey distributed at the start of the term). Outcome expectations demonstrate a student's intentions for a research-oriented career in STEM; this variable was measured on a four-point Likert scale (4-point scale ranging from (1 = "very unlikely" to 4 = "very likely").

Exogenous variables. The other variables used in the analysis map nicely onto SCCT's (Lent, et al., 1994) notions of *personal inputs, students' background* and *contextual influences.* In this study, these notions are measured by students' precollege characteristics, college experiences, classroom experiences, and faculty perceptions. *Personal inputs* control for a student's gender, race (measured URM vs. Non-URM), and whether the student speaks English as a native language. *Background characteristics* are measured from the mother's education level and family household income. Pre-college *experiences* control for prior academic achievement, specifically years of biology taken in high school and participation in STEM research programs. Student perceptions of their STEM abilities are accounted for by the STEM self-concept construct (see Appendix B. for the items that comprise this construct), which is a component of the SCCT theory. *Contextual influences* are categorized in three areas: student perceptions of environmental conditions, student college experiences, and faculty perceptions of their teaching practices. Further, in class experiences were controlled for using multiple measures such as the frequency of participating in class discussions or use of hands-on activities. Students' college experiences focused on the role of co-curricular activities such as structured undergraduate research programs in shaping student's research-career aspirations. In addition, a variable specifically examining students' engagement in research with faculty is included. The model also specifies faculty-level variables (captured in the survey administered to faculty) and includes items about the pedagogical practices they use in the classroom and their expectations of students. Discipline of the introductory course also accounts for distinctions in context and content of courses: Computer Science, Engineering, and Mathematics were grouped separately from Physical Sciences (Chemistry) and introductory Biological Sciences was the referent category. All of the variables used in the model, along with their coding schemes, are summarized in Appendix A.

Missing Data

In order to maximize the sample available for analysis, missing data were replaced for the larger dataset, wherever appropriate, in a multi-step process. First, we removed from the sample all students who had missing data on one of the dependent variables and students who were missing information on key demographic characteristics such as gender, race, or native language. In total, 19 students were missing information in one or more of these areas (< .5%). For the remaining variables of interest, we analyzed the extent to which missing data occurred. Overall, there was very little missing data; only three variables had more than 3% of its cases missing. Given the relatively few instances of missing data across the variables used in the analysis, we imputed missing data using the expectation-maximization (EM) algorithm in SPSS. The EM algorithm employs maximum likelihood estimation techniques to impute values for cases with missing data. Because EM uses most of the information available in the dataset to produce the imputed values, it is a more robust method of dealing with missing data than listwise deletion or mean replacement (Allison, 2002; Dempster, Laird, & Rubin, 1997; McLachlan & Krishnan, 1997). Distributions of variables were compared before and after missing values were imputed, and were found to be virtually identical. Next, we split the data into two datasets, one comprised of only URM students and the other comprised of everyone else in order to replicate the same model across groups.

Hierarchical Linear Modeling

First**,** descriptive statistics of the means were ran (See Tables 1 for a full list of the descriptive statistics for each variable). Second**,** hierarchical linear modeling was performed on two models – one for the URM students and the other for the non-URM students. The variables in each model were identical. Performing single-level analyses with multi-level data can underestimate the standard errors of model parameters, increasing the likelihood of committing Type-I statistical errors (de Leeuw & Meijer, 2008; Raudenbush & Bryk, 2002). Specific to this study, a positive regression coefficient indicates that a student is more likely to pursue a scientific research career and a negative coefficient implies that the student is less likely to enter scientific research. Finally, to allow for comparisons of the effect of independent variables on the outcomes of interest between the two student groups (i.e. URM and non-URM), we used the equation offered by Paternoster, Brame, Mazerolle, & Piquero (1998) for independent samples, using the equation:

$$Z = \frac{b_1 - b_2}{\sqrt{SEb_1^2 + SEb_2^2}}$$

This equation statistically tests for the equality of regression coefficients and allows for the systematic comparison of the predictors (see Table 3 for z-scores from the equality of regression coefficient test for independent variables that were significant for both URM and non URM students).

The multilevel analyses for this study were conducted in several steps. First, a null model with no predictor variables was created for each of the models to determine the intraclass correlation coefficient for each (ICC). The ICC measures the proportion of the variance in the outcome that is between level-2 units (Raudenbush & Bryk, 2002), which in this case is between classroom environments. In this study, the proportion of variance between classrooms ranges from 2.8% for the non-URM model and 4.7% for the URM model. Because the variation in our outcomes between groups was statistically significant ($p<.001$), we decided to proceed with HLM. This type of analysis is timely given calls for faculty at colleges and universities to examine their role in shaping students' career aspirations; such analysis contributes to an understanding of the role that the classroom context plays in stimulating interest in STEM research careers (Maton & Hrabowski, 2004).

Prior literature on pedagogical practices in the classroom and conceptual frameworks regarding Social Cognitive Career Theory guided the selection of the variables used in the models (Lent, Brown, & Hackett, 1994). In the analyses, variables were added in conceptually related, temporally sequenced blocks. First, student demographic characteristics (e.g., sex, English native language, and socioeconomic status) were added to the models. Next, several pre-college measures (e.g., prior academic preparation, high school activities, and degree aspirations) were added to see if any observed differences between students could be accounted for by differences in these areas (Astin, 1993).

Thirdly, we added to the models students' in-class experiences, which includes both behaviors (e.g., actively participated in class discussion, hours per week talking with faculty outside of class or office hours) and attitudes about both others and themselves (e.g. faculty here are interested in students' academic problems, students' academic self-concept). Variables in this block were derived from the Science Student Experience Post Questionnaire. Finally we added out-of-classroom college experiences such as hours per week working on research with faculty. We ran identical models for both URM and non-URM students. Appendix A contains a complete list of the variables in the analysis and their corresponding coding schemes. Appendix B provides the individual items of the constructs that were included in the model.

Limitations

This study is limited in several important ways that must be taken into account when interpreting findings. First, while the study builds on prior literature by assessing the factors contributing to students' aspirations in pursuing a STEM research career, data derived from 76 classes across 15 universities may not be representative of the population of introductory STEM courses across the nation. Our weighting procedure increases our confidence that the findings are generalizable to the population of students in these 76 classes, but caution should be exercised before generalizing these findings to the universe of introductory STEM courses in the United States.

Secondly, since this analysis relies heavily on survey data, and our analysis could be limited by study participants' ability to recall experiences. Although any analysis using survey data is susceptible to this sort of bias, research has demonstrated very strong correlations between self-reports and what is actually occurring . For instance, a comparison of students' self-reported grades and their actual grades were found to be quite similar (Baird, 1976).

Furthermore, in many instances there is no other practical way to collect data about a specific topic without relying on self-reports (Astin,1993); therefore, although the use of these measures are imperfect, they are necessary.

Descriptive Statistics

URM student sample. URM students comprised 25% of the total sample of students who completed the pre- and post-surveys. Approximately 61.1% of the URM sample identified as female. Roughly 68.9% of students had indicated that they had a family income of $79,999 or less. Sixty three percent of students came from household wherein the students' mothers had less than a bachelor's degree. Seventy-four percent of students indicated that English was their native language. Approximately 23.3% of URMs participated in a math, science, or engineering programs before entering college, and majority of the students came from public high schools (80.4%). Roughly 64% of the URMs in the sample were in their first year of college, with another 27.5% percent taking the survey during their second year. Seventy-five percent of URM students where declared STEM majors. At the beginning of the term 38% URMs expressed that they were "somewhat likely" to pursue a career that included conducting scientific research and 31% reported that they were "very likely" to do the same. At the end of the academic term, the proportion of the URMs who indicated that they were "somewhat likely" or "very likely" to pursue a career that included conducting scientific research shifted to 29.5% and 13.1% respectively. (See Table 1 for the descriptive statistics on all of the variables in the URM model).

Non-URM student sample. Non-URM students comprised 75% of the sample of students who completed the pre and post questionnaires. Approximately 54.7% of the sample identified as female. Roughly 43.4% of students had indicated that they had a family income of $79,999 or less. On average, 39% of students came from household where the mother had less than a bachelor's degree. Eighty-two percent represented in the non-URM student sample indicated that English was their native language. Precisely 14.9% of non-URMs participated in a math, science, or engineering programs before entering college, and majority of the students came from public high schools (76.7%). Roughly 65.5% of the non-URMs in the sample were in their first year of college, and another 24.1% percent took the survey during their second year. Seventy percent of the non-URM students in the sample where declared STEM majors. At the beginning of the term 40.4% non-URMs expressed that they were "somewhat likely" to pursue a career that included conducting scientific research and another 24.3% reported that they were "very likely" to do the same. At the end of the academic term, the proportion of non-URMs who indicated that they were "somewhat likely" or "very likely" to pursue a career that included conducting scientific research decreased to 27.6% and 10.2% respectively.

Findings

HLM Models

There were four variables that were significant predictors of the dependent variable for both URM and non-URM students, however the effect of these factors sometimes differs for URM and non-URM students. First, for both groups those students who expressed a higher interest in pursuing a career that includes conducting scientific research at the beginning of the term tend to have a higher interest in a research career at the end of the term. The effect of the pre-test on students' later aspirations for a research career was the same for both groups according to the equality of regression coefficient test (See Table 3. for the z-scores). Further students who feel closer to reaching their professional goals after completing the introductory STEM course are also more likely to be interested in a research career in STEM – the effect of this variable was similar for both groups. Further, students – both URM and non-URM – who strongly agree that their career goal is to improve the health of minority communities report a greater interest in research careers at the end of the academic term. It is important to note that the effect of this career goal, while mattering to both groups, was more pronounced for URM students (according to the test of equality of coefficients and also differences in t-ratios for URM 4.08*** compared with non-URM 2.21*). Lastly, students in classrooms where faculty more strongly agree that they are provided with the resources that they needed to do their best work as a teacher were less likely to express strong interest in scientific research careers. Another way of stating this is that faculty who feel they do not have the resources they need to do their best work as a teach also tend to have students that are more likely to pursue a research career. This is finding affects both groups similarly and may indicate more resources are needed or that faculty who care about their teaching are doing their best to encourage research careers among students and understand that more is needed to fulfill these outcome expectations.. More research is needed to determine why this is so. Although there are several variables non-URM and URM students share in terms of predicting interest in research STEM careers, there are meaningful differences between the two groups. The subsequent sections will discuss the findings that were unique for each group, which demonstrates how the experiences within STEM introductory classes differ for URMs and non-URM students.

URM students. The pre-test accounts for 10.66% of the student-level variance in the likelihood that students aspired to pursue a scientific research career by the end of the academic term. This variable is notably the strongest predictor of the dependent variable in the model. The proportion of variable explained drops slightly to 10.49% after accounting for demographic characteristics (none of which were significant) and jumps to 16.23% once aspects of students' pre-college preparation, achievement and experiences are accounted for. The variance surges to 22.30% once students' experiences occurring within the classroom environment enter the model and increases slightly to 25.16% once controlling for students' experiences that occurred within the larger college environment. The variance shifts a bit to 25.19% once discipline-level variables are added to the model but it generally appears that there are no differences in discipline/content across the introductory courses.

There were four factors that distinctly shape career aspirations among URM students, but do not significantly influence their non-URM peers. The opposite is also true—several factors matter to non-URM students but not their URM counterparts. Specifically, two precollege preparation/experience variables are significant for URM students, with neither being significant for the non-URM student group: participation in a pre-college STEM program and earning higher grades in high school biology positively predicts URM students' aspirations for a research career. When looking at students' experiences within the classroom context, two are uniquely significant for URM students but not their non-URM peers. URM students in classes with faculty who more frequently relate scientific concepts to real-world problems are more likely to be interested in a career in research. Contrary to expectations, the findings show that URM students are more likely to express interest in scientific research careers when the faculty member teaching the class indicated that they spent fewer hours per week meeting with students during designated office hours. It may well be that there are learning assistants or supplemental instruction or other activities that effectively reduce student use of office hours, a factor that was unaccounted for in the model. It also may indicate that faculty are being more effective in the classroom if less time is spent in office hours.

Non-URM students. The pre-test accounts for 10.56% of the student-level variance in the likelihood that students aspired to pursue a scientific research career at the end of an academic term. This proportion remain stagnant at 10.67% after accounting for demographic characteristics. The variances rises slightly to 11.47% when controlling for students' pre-college preparation, achievement and experiences. The variance jumps to 17.52% once students' experiences occurring within the classroom environment enters the model, and rises again to 18.13% once controlling for experiences occurring within the larger college environment. The variance increases modestly to 18.30% once discipline-level variables are added to the model, indicating that again no disciplinary differences were detected across classrooms. A discussion of the final model as it pertains to the non-URM students follows.

There are a three classroom variables that significantly predict career aspirations for non-URM students but not their URM counterparts. First, students who more strongly agree that they see the real-life application or relevance of what they learn within the class are more likely to be interested in a career in research. Second, there is a negative association between the number of hours per week faculty report spending with undergraduates working on research and the propensity that non-URM students are likely to indicate aspirations for pursuing a career in scientific research. In other words, the more time faculty report working on research with students, the less likely non-URM students were to indicate interest in a STEM research career enrolled in their introductory courses. This may have been a proxy for hours spent in research, but this merits closer examination. Second, the proportion of A's earned within an introductory STEM course positively predicted career aspirations – the more A's that an instructor gave out by the end of the term, the more likely students were to answer that they wanted to pursue a career in research. Further, of the two variables that accounted for aspects of the larger college environment, only one was significant – the more frequently students conducted an experiment the more likely they were to indicate that they were interested in STEM research careers.

Discussion and Conclusion

Students' experiences in the contexts of the classroom and the larger college environment affect students in numerous ways, with one important outcome being the type of career students aspire to fill once they graduate. Since the emphasis of this study is on the impact of classroom practices instructors use in STEM classrooms, we first begin identifying the implications this study has within that context. First, using the SCCT lens to understand how students' career aspirations are shaped within the context of the classroom, we already suspected that there would be certain classroom experiences more effective at turning students on to a research career. The fact that several factors of the classroom environment were significant in the analysis signifies that faculty indeed play a pivotal role in informing student's career aspirations (Maton & Hrabowski, 2004). For example, for both URM and non-URM students, the relevancy of what they are learning in the classroom applied to real life is an important pedagogy and content approach. The clearer students were able to see this connection, the more likely they were to indicate that they aspired to a research career. Relating concepts to the real world for URM students will likely be most impactful if faculty make connections that show how STEM concepts and practices impact the communities students come from. Many students, for example, likely do not know that certain science-based health and environmental phenomenon affect particular minority ethnic groups more than others or that unethical research practices have occurred on individuals from minority backgrounds, or that research that uplifts minority communities is often not pursued by mainstream scientists. By connecting what is taught to students' histories and futures, faculty can more effectively turn students on to research careers.

Other findings from this study show that values drive students' aspirations and are important considerations in understanding career development. For instance, students who had a greater commitment to improving the health of minority communities were more likely to express stronger interest in pursuing a STEM research career among both URM and non-URM students, with an even greater impact on URM student aspirations. This finding reinforces the need for instructors to connect course concepts to real life and to demonstrate to students how what they are learning can be applied in ways that are of real societal benefit, especially to minority communities. Similarly students want to feel empowered by what they learn in their classes – students, URM and non-URM alike, are more likely to aspire for a research career if they felt the class helped them get closer to reaching their professional goals. Although it is uncertain exactly what instructors did to make students feel like their professional goals was more in reach, a brief discussion of relevant STEM careers for example, what they entail, and the next steps needed to realize those dreams may be a helpful exercise. Findings show that many engaging activities in the study had no significant direct effect on students' research career aspirations. This should be a focus of study of indirect effects to identify more strategies to improve students' research career aspirations. It may also reflect, however, that few students experience these practices in large introductory courses. Unfortunately, many STEM faculty do not often infuse their class with practical, engaging activities and many – even if they are interested in bettering their class for the sake of their students – do not know where to start since they never had training on evidence-based practices or what it means to be an effective teacher. Indeed, many faculty rely on teaching select scientific concepts to students and simply require that students memorize definitions and algorithmic methods for problem solving (Bates, & Galloway, 2012).

Campus leadership can empower faculty by ensuring the resources are available that will help them become better instructors as they do more activities that push students to think critically via the actual application of scientific concepts (Barnett & Ceci, 2002). For example some institutions have centers for teaching and learning, wherein faculty can take workshops about effective pedagogies in STEM classrooms that are based on empirical research or sit one-on-one with a center consultant and review the type of pedagogies they can infuse in their existing curriculum to make it more engaging. Teaching centers also increase the faculty's awareness of the need for diversified teaching practices, so that students from all backgrounds can develop an excitement for learning STEM related content and developing their STEM competencies. Another caveat is that faculty have many demands on their time, and restructuring a class so that it takes more of an active learning nature is time intensive. Thus, if administration sees value in making STEM classrooms more engaging, they will have to incentivize or reward excellent teaching – or at the very least make sure that faculty who volunteer to transform their classes also have the option of taking a course release. By supporting STEM faculty in improving their teaching, the institution conveys a message that meaningful student learning is highly valued.

Further, it is important to note that just because student background characteristics and pre-college experiences have a large impact on students' career aspirations, does not mean that institutions are absolved of their responsibility to take action. Indeed, there are still many actions institutions can take to support student career aspirations so that they are focused towards research careers in STEM. For example the finding that the pre-test was the strongest predictor of students' aspirations for STEM research careers implies that there needs to be a greater emphasis on developing the research aspirations of students early on and prior to college. To do so, colleges and universities should partner with K-12 institutions to foster educational initiatives that improve pedagogical practices used by STEM teachers in the classroom and to increase the number and quality of K-12 programs that bolsters students' interest in research. Understandably, faculty at institutions of higher education have the expertise to insure that programming and changes in pedagogy at the K-12 level is informed by best-practices. Leveraging partnerships with K-12 institutions allows colleges and universities to more strongly shape students' career interests, academic ability, and skills for scientific research because they are reaching students at a time when they are young, highly impressionable, and just beginning to figure out where their interests and strength lay.

Similarly, we examined the effect that structured high school research programs had on students' career aspirations and found that these programs were significantly influential for URM students in particular. This finding reaffirms the significant monetary contributions of government and non-profit entities like the National Science Foundation, National Institutes of Health, and Howard Hughes Medical Institute that fund interventions targeting URM students thereby helping these students develop STEM competencies and build social networks. Having a strong content knowledge in STEM and having relationships with some of the seasoned players in the STEM domain represent valuable capital that can be cashed in once students enter the workforce or apply to graduate/ professional school in STEM fields (Seymour et al., 2004). If possible, foundations and government should consider increasing the funding they provide for research programs at the K-12 level. To encourage institutions to partner with nearby K-12 institutions, foundations should also consider providing money for course releases for the faculty involved in these K-12 partnerships. This would offset some of the time devoted to successfully implement programs.

Returning to the theory underlining this study, although SCCT offers a framework for understanding how STEM students' experiences in the classroom and larger college environment impact career aspirations in STEM, one area where the theory did not apply surprisingly was with respect to self-efficacy and the importance self-efficacy theoretically is supposed to have on the development of career aspirations and choices. We, therefore, intentionally added a construct that measured academic ability, science ability, critical thinking, math ability and drive to achieve all which we call STEM self-concept. Given that STEM self-concept was not significant for either student group, future research should test other constructs that also measure self-efficacy to determine if a more robust measure exists or alternatively if SCCT needs modifications when applied to STEM students to properly understand their career aspirational development. Further research should also disaggregate across STEM research careers (i.e. engineering, biological sciences, etc.) to investigate how the factors used within this study vary by discipline. Additional analysis across racial groups may provide more specific information about what is most important for promoting STEM research career aspirations, since this study aggregates underrepresented populations into one group. This type of research would better inform initiatives that strive to increase the diversity within the STEM talent pool, which would in turn enrich the type of research conducted via a multiplicity of perspectives and more creative solutions to problems. Finally it is also noteworthy that the analytical models in this study, predicted very little of the student-level variance with respect to the dependent variable, both for URM students and their majority peers. This suggests that more research is needed to determine the impact pedagogical practices have on shaping students' career interests. Since there are likely many nuances in the pedagogical practices and classroom experiences that develop students' aspirations for scientific research, qualitative studies may better disentangle how classroom pedagogy translates to heightened interest in a research career in STEM.

In conclusion, in order to meet the national call for additional researchers in STEM, institutions must make sure they are cultivating students' interest for this career pathway – and the first mode of doing so is in STEM introductory classrooms. Further, given the national priority to expand participation among URM students in the STEM workforce, particularly in research careers, investigating how faculty and the classroom experience influence career aspirations is critical for advancing these workforce initiatives. This study contributes to existing literature by identifying classroom pedagogical practices that make it more likely that students will report they are interested in a scientific research career at the end of an academic term in which they took an introductory STEM course. Further comparing results across student groups teases out some of the different and overlapping needs of URM students compared to their majority counterparts – a distinction that is most definitely needed in higher education if it is to meet the charge of better supporting STEM students' career aspirations.

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Table 1.

Descriptive Statistics for Predicting the Likelihood Students in an Introductory STEM Course Plan to Pursue a STEM Research Career

	***URMs* (n=679)**				**Non-URMs *(n=2526)***			
	Mean	St. Dev.	Min	Max	Mean	St. Dev.	Min	Max
Dependent variable								
Pursue a career that includes conducting STEM research	2.30	1.06	1	4	2.13	0.99	1	4
Pre-Test								
Pursue a career that includes conducting STEM research (Pretest)	2.94	0.94	1	4	2.78	0.94	1	4
Demographic Characteristics								
Gender (Female)	1.62	0.49	1	2	1.55	0.50	1	2
Income	4.13	2.21	1	8	5.49	2.08	1	8
Mother's Education	3.61	1.98	1	9	4.59	1.85	1	9
English Your Native Language	1.74	0.44	1	2	1.83	0.38	1	2
Students' Classroom Environment Experiences								
HS Biology Grade	5.48	0.83	1	4	5.67	0.79	1	4
HS Math, science, or engineering Research Program	1.22	0.41	1	2	1.14	0.35	1	2
HS Research-focused program	1.06	0.23	1	2	1.05	0.22	1	2
STEM Self-Concept	-0.12	0.89	Continuous		0.04	0.90	Continuous	
Students' Classroom Environment Experiences								
Student Responses								
Frequency: Participated in class discussions	2.78	1.27	1	5	3.01	1.24	1	5
Percentage of Class: Using Hands-on activities	1.98	1.39	1	7	1.97	1.33	1	7
Agreement: coursework emphasized applying concepts	2.88	0.71	1	4	2.81	0.71	1	4
I Saw The Real-Life Application or Relevance of What I Learned	2.83	0.77	1	4	2.81	0.78	1	4
I Was Well-Prepared for the Difficulty Level of This Course	2.67	0.84	1	4	2.83	0.75	1	4
I Feel Closer to Reaching My Professional Goals After Completing this Course	2.71	0.84	1	4	2.71	0.80	1	4
I Received Feedback that Helped Me Learn and Improve	2.66	0.83	1	4	2.60	0.78	1	4
Collaboration Among Students in the Course	2.89	1.15	1	5	2.94	1.13	1	5
Used Technology Effectively to Engage Students	3.11	0.90	1	4	3.14	0.82	1	4
Cared about Students' Diverse Life Experiences	2.99	0.79	1	4	3.11	0.75	1	4

Table 1. Cont.

Descriptive Statistics Predicting the Likelihood Students in an Introductory STEM Course Plan to Pursue a STEM Research Career

	***URMs* (n=679)**				**Non-URMs *(n=2526)***			
	Mean	St. Dev.	Min	Max	Mean	St. Dev.	Min	Max
Did You Have a Teaching Assistant for this Course	1.55	0.50	1	2	1.49	0.50	1	2
Faculty Responses								
	Mean	St. Dev.	Min	Max	Mean	St. Dev.	Min	Max
Frequency: Relate scientific concepts to real-world problems	3.96	0.99	1	5	4.06	1.04	1	5
Frequency: Synthesize several sources of information	3.24	1.20	1	5	3.51	1.10	1	5
To what Extent: Learn effectively on their own	2.62	0.49	1	3	2.48	0.50	1	3
To what Extent: Solve complex, real-world problems	2.23	0.56	1	3	2.18	0.65	1	3
HPW: Working with undergraduates on research	1.74	0.99	1	9	1.84	0.94	1	9
HPW: Teaching (actual classroom time)	3.30	1.06	1	9	3.15	0.92	1	9
HPW: Meeting students during office hours	2.58	0.89	1	9	2.57	0.90	1	9
Agreement: I am provided with the resources that I need to do my best work as a teacher	2.83	0.91	1	4	2.89	0.78	1	4
Larger College Environment Experiences								
Frequency: Conducting an Experiment	3.07	1.09	1	5	3.24	1.05	1	5
Improving the Health of Minority Communities	3.22	0.80	1	4	2.76	0.88	1	4
Discipline-Level Variables								
Biological Science (Referent Group)	0.26	0.44	0	1	0.26	0.44	0	1
Computer Science, Engineering, Mathematics Classes	0.40	0.49	0	1	0.38	0.49	0	1
Physical Science Classes	0.33	0.47	0	1	0.34	0.48	0	1

The URM sample included 66 introductory STEM classrooms at 15 institutions. The non-URM sample included 68 introductory classrooms at 15 institutions.

Table 2.

Results of HLM Model Predicting the Likelihood Students in an Introductory STEM Course Plan to Pursue a STEM Research Career

	URMS (*n=622*)						Non-URMS (*n=2362*)					
Student-Level Variables (Level-1)	**R^2**	**r**	**β**	**SE**	**T-ratio**	**Sig**	**R^2**	**r**	**β**	**SE**	**T-ratio**	**Sig**
Pre-Test	**10.66%**						**10.56%**					
Pursue a career that includes conducting STEM research		0.36	0.26	0.05	4.81	***		0.34	0.30	0.02	12.13	***
Demographic Characteristics	**10.49%**						**10.67%**					
Gender (Female)		-0.02	-0.07	0.11	-0.67			-0.02	-0.01	0.05	-0.24	
Income		-0.09	-0.02	0.03	-0.93			-0.05	-0.01	0.01	-1.04	
Mother's Education		-0.14	0.01	0.03	0.03			0.02	0.02	0.01	1.39	
English Your Native Language		0.00	0.01	0.12	0.13			-0.01	0.02	0.06	0.27	
Pre-college preparation, Achievement and Experiences	**16.23%**						**11.47%**					
HS Biology Grade		0.13	0.17	0.06	2.81	**		0.02	0.01	0.03	0.22	
HS Math, Science, or Engineering Research Program		0.18	0.34	0.12	2.82	*		0.03	0.02	0.07	0.27	
HS Research-Focused Program		0.09	0.03	0.24	0.11			0.02	0.00	0.11	-0.03	
STEM Self-Concept		0.18	0.00	0.06	0.03			0.13	0.04	0.03	1.51	
College Experience (Responses taken from the Post-Survey)												
Students' Classroom Environment Experiences	**22.30%**						**17.52%**					
Student Responses												
Frequency: Participated in Class Discussions		0.12	0.02	0.04	0.61			0.10	0.02	0.02	0.80	
Percentage of Class: Using Hands-on Activities		0.09	0.02	0.04	0.46			0.07	0.02	0.02	0.96	
Agreement: Coursework Emphasized Applying Concepts to Practical Problems		0.12	-0.07	0.08	-0.89			0.13	0.03	0.04	0.71	
I Saw The Real-Life Application or Relevance of What I Learned		0.15	0.01	0.08	0.09			0.19	0.14	0.04	3.77	***
I Was Well-Prepared for the Difficulty Level of This Course		0.08	-0.07	0.07	-1.02			0.11	0.03	0.04	0.72	
I Feel Closer to Reaching My Professional Goals After Completing this Course		0.20	0.21	0.07	2.96	**		0.19	0.08	0.04	2.25	*
I Received Feedback that Helped Me Learn and Improve		0.10	-0.03	0.07	-0.37			0.09	-0.06	0.03	-1.69	
Collaboration Among Students in the Course		0.15	0.00	0.05	-0.01			0.12	0.04	0.02	1.79	
Used Technology Effectively to Engage Students		0.08	-0.02	0.07	-0.32			0.06	-0.04	0.03	-1.18	
Cared about Students' Diverse Life Experiences		0.10	0.00	0.07	-0.04			0.09	0.04	0.03	1.08	
Did You Have a Teaching Assistant for this Course		-0.12	-0.20	0.11	-1.86			-0.02	0.00	0.05	0.07	

Table 2 Cont.

Results of HLM Model Predicting the Likelihood Students in an Introductory STEM Course Plan to Pursue a STEM Research Career

	URMS (*n=622*)						Non-URMS (*n=2362*)					
	R^2	**r**	**β**	**SE**	**T-ratio**	**Sig**	**R^2**	**r**	**β**	**SE**	**T-ratio**	**Sig**
Faculty responses												
Frequency: Relate Scientific Concepts to Real-World Problems		0.08	0.15	0.06	2.54	*		0.04	0.03	0.03	0.90	
Frequency: Synthesize Several Sources of Information		0.02	-0.07	0.05	-1.44			0.03	-0.04	0.02	-1.57	
To what Extent: Learn Effectively on Their Own		0.00	0.05	0.12	0.38			0.04	0.05	0.05	0.93	
To what Extent: Solve complex, Real-World Problems		-0.08	-0.02	0.10	-0.25			0.03	0.05	0.04	1.24	
HPW: Working with Undergraduates on Research		0.00	0.07	0.06	1.28			-0.05	-0.09	0.03	-3.13	**
HPW: Teaching (actual classroom time)		0.04	0.05	0.06	0.80			0.00	0.05	0.03	1.46	
HPW: Meeting Students During Office Hours		-0.15	-0.21	0.08	-2.71	**		0.01	-0.02	0.03	-0.58	
I am provided with the resources that I need to do my best work as a teacher		-0.14	-0.17	0.06	-2.77	**		-0.07	-0.10	0.03	-3.01	**
Proportion of "A" Grades in Class			0.12	0.47	0.25				0.46	0.22	2.13	*
Larger College Environment Experiences	**25.16%**						**18.13%**					
Frequency: Conducting an Experiment		0.20	0.02	0.05	0.40			0.16	0.07	0.02	2.77	**
Improving the Health of Minority Communities		0.33	0.25	0.06	4.08	***		0.11	0.06	0.03	2.21	*
Discipline-Level Variables (Level-2)	**25.19%**						**18.30%**					
Computer Science, Engineering, and Mathematics		0.02	0.06	0.17	0.36			-0.03	-0.13	0.07	-1.81	
Physical Science		0.00	0.07	0.14	0.51			-0.04	-0.07	0.07	-1.12	

*Note: *Indicates p-value less than .05; ** Indicates p-value less than .01; *** Indicates p-value less than .001. The URM sample included 66 introductory STEM classrooms at 15 institutions. The non-URM sample included 68 introductory classrooms at 15 institutions.*

Table 3.

Comparing Significant Coefficients for Predicting the Likelihood Students in an Introductory STEM Course Plan to Pursue a STEM Research Career

	URM STEM			**NON-URM STEM**				
Variables	**Final *b***		**s.e.**	**Final *b***		**s.e.**	**z score**	**What this means**
Pursue a career that includes conducting STEM research	0.26	***	0.05	0.30	***	0.02	0.77	Affects both groups similarly
I Feel Closer to Reaching My Professional Goals After Completing this Course	0.21	**	0.07	0.08	*	0.04	-1.67	Affects both groups similarly
I am provided with the resources that I need to do my best work as a teacher	-0.17	**	0.06	-0.10	**	0.03	1.04	Affects both groups similarly
Improving the Health of Minority Communities	0.25	***	0.06	0.06	*	0.03	-2.92	Affects both groups, but more pronounced in URMS -2.92

Notes. ***p<.001, **p<.01, *p.05. Z scores that fall outside the range of -1.96 and +1.96, indicate a p-value of less than .05, and demonstrate that the beta coefficients between URM students and Non-URM students are statistically different. See article by Paternoster and colleagues (1998) for equation to test for the equality of regression coefficients. A Z-test was only performed if beta coefficients for a given variable were significant for both groups.

Appendix A

Variables and Coding

Variable	Coding Scheme
Dependent variable	
Pursue a career that includes conducting STEM research	1 Very unlikely, 2 Somewhat unlikely, 3 Somewhat likely, 4 Very likely
Pre-Test	
Pursue a career that includes conducting STEM research (Pretest)	1 Very unlikely, 2 Somewhat unlikely, 3 Somewhat likely, 4 Very likely
Demographic Characteristics	
Gender (Female)	1 Male; 2 Female
Income	1 Less than $20,000…8 More than 200,000
Mother's Education	1 Junior high/Middle school or less; 2 Some high school; 3 High school graduate; 4 Postsecondary school other than college; 5 Some college; 6 College degree; 7 Some graduate school; 8 Graduate degree
English Your Native Language	1 No; 2 Yes
Pre-college preparation, achievement and experiences (Responses taken from Pre-Survey)	
HS Biology Grade	1 F…5 A
HS Math, science, or engineering Research Program	1 No; 2 Yes
HS Research-focused program	1 No; 2 Yes
STEM Self-Concept	Continuous
College Experience (Responses taken from the Post-Survey)	
Students' Classroom Environment Experiences	
Student Responses	
Frequency: Participated in class discussions	1 Never; 2 Seldom; 3 Sometimes; 4 Often; 5 Very often
Percentage of Class: Using Hands-on activities	1" 0%"… 7 "100%"
Agreement: The coursework emphasized applying concepts to practical problems	1 Strongly disagree; 2 Disagree; 3 Agree; 4 Strongly agree
I Saw The Real-Life Application or Relevance of What I Learned	1 Strongly disagree; 2 Disagree; 3 Agree; 4 Strongly agree
I Was Well-Prepared for the Difficulty Level of This Course	1 Strongly disagree; 2 Disagree; 3 Agree; 4 Strongly agree
I Feel Closer to Reaching My Professional Goals After Completing this Course	1 Strongly disagree; 2 Disagree; 3 Agree; 4 Strongly agree
I Received Feedback that Helped Me Learn and Improve	1 Strongly disagree; 2 Disagree; 3 Agree; 4 Strongly agree

Appendix A Cont.

Variables and Coding

Variable	Coding Scheme
Dependent variable	
Collaboration Among Students in the Course	1 Never; 2 Seldom; 3 Sometimes; 4 Often; 5 Very often
Used Technology Effectively to Engage Students	1 Strongly disagree; 2 Disagree; 3 Agree; 4 Strongly agree
Cared about Students' Diverse Life Experiences	1 Strongly disagree; 2 Disagree; 3 Agree; 4 Strongly agree
Did You Have a Teaching Assistant for this Course	1 No; 2 Yes
Faculty Responses	
Frequency: Relate scientific concepts to real-world problems	1 Never; 2 Seldom; 3 Sometimes; 4 Often; 5 Very often
Frequency: Synthesize several sources of information	1 Never; 2 Seldom; 3 Sometimes; 4 Often; 5 Very often
To what Extent: Learn effectively on their own	1 Not at all; 2 To some extent; 3 To a great extent
To what Extent: Solve complex, real-world problems	1 Not at all; 2 To some extent; 3 To a great extent
HPW: Working with undergraduates on research	1 None; 2 "1-4"; 3 "5-8"; 4 "9-12"; 5 "13-16"; 6 "17-20"; 7 "21-34"; 8 "35-44"; 9 "45+
HPW: Teaching (actual classroom time)	1 None; 2 "1-4"; 3 "5-8"; 4 "9-12"; 5 "13-16"; 6 "17-20"; 7 "21-34"; 8 "35-44"; 9 "45+
HPW: Meeting students during office hours	1 None; 2 "1-4"; 3 "5-8"; 4 "9-12"; 5 "13-16"; 6 "17-20"; 7 "21-34"; 8 "35-44"; 9 "45+
Agreement: I am provided with the resources that I need to do my best work as a teacher	1 Strongly disagree; 2 Disagree; 3 Agree; 4 Strongly agree
Larger College Environment Experiences	
Frequency: Conducting an Experiment	1 Never; 2 Seldom; 3 Sometimes; 4 Often; 5 Very often
Improving the Health of Minority Communities	1 Not Important; 2 Somewhat Important; 3 Very Important; Essential
Discipline-Level Variables (Level 2)	
Biological Science Classes (referent group)	Continuous
Computer Science, Engineering, Mathematics Classes	Continuous
Physical Science Classes	Continuous

Appendix B

Factor Items and Loadings

Factor	**Item**	**Loadings**
STEM Self-Concept (CSS)- A unified measure of students' beliefs about their STEM abilities and confidence in academic environments.		
	Academic ability	.85
	Science ability	.71
	Critical thinking skills	.69
	Mathematics ability	.57
	Drive to achieve	.55