From Gatekeeping to Engagement: A Multicontextual, Mixed Method Study of Student Academic Engagement in Introductory STEM Courses

Josephine Gasiewski, Kevin Eagan, Gina Garcia, Sylvia Hurtado, Mitchell Chang

University of California, Los Angeles

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Contact: Josephine Gasiewski, 405 Hilgard Ave., 3005 Moore Hall, University of California, Los Angeles, CA 90095-1521; Phone: (310) 983.3053; Email: joski@ucla.edu

Abstract

Introductory courses in the sciences have been criticized for their lack of engaging pedagogy and their encouragement of passive learning techniques. Critics have cited these features as primary reasons why students decide to leave the sciences shortly after enrolling in college, as students report feeling un-engaged in learning and confused about course content. Using a sequential, explanatory mixed methods approach, this study provides an in-depth look at the relationship between student learning strategies, faculty pedagogical techniques, and student engagement in introductory science, technology, engineering, and mathematics (STEM) courses. Quantitative survey data are drawn from 2,873 students within 73 introductory STEM courses across 15 colleges and universities while qualitative data were collected from 41 student focus groups at eight institutions. Findings indicate that freshmen and pre-med students report higher levels of engagement. Additionally, students who feel comfortable asking questions in class, seek out tutoring, attend supplemental instruction sessions, and collaborate with other students in the course are also more likely to be engaged. At the course-level, student engagement is increased when faculty signal an openness to student questions and recognize their role in helping students to succeed. Findings from this study point to ways that instructors of introductory STEM courses can adjust their pedagogical techniques and improve their classroom climates to encourage greater levels of engagement from students.

Introduction

In describing the culture of science, Daryl Chubin, director of the American Association for the Advancement of Sciences' Center for Advancing Science & Engineering Capacity stated: "Not everybody is good enough to cut it, and we're going to make it hard for them, and the cream will rise to the top" (Epstein, 2006). Nowhere is this more evident than in introductory "gatekeeper" courses, those initial introductory college math and science courses which function to eliminate all but the 'top tier' students and champion the concept that "scientists are born, not made" (Tobias, 1990, p.11). It is within the first two years of taking these courses that the majority of attrition in the sciences occurs in college (Chang, Cerna, Han, & Saenz, 2008; Seymour & Hewitt, 1997). In fact, Seymour and Hewitt (1997) identify STEM students' performance in introductory courses as one of the key indicators as to whether students switch out of their intended STEM majors during college.

Scholars have linked these high attrition rates to several factors, including a reliance on large lecture-based courses and lack of engaging pedagogy. Although it may represent an efficient method for presenting a tremendous amount of content to a large audience, lecture tends to encourage one-way, passive, superficial learning (Bransford et al., 2000; Moore, 1996; Seymour & Hewitt, 1997). Additionally, lectures tend to promote memorization over conceptual understanding (Bligh, 2000; Booth, 2001; Knight & Wood, 2005; Novak, 2002). Indeed, college-level introductory science and mathematics courses tend to focus too much on the acquisition of content knowledge through memorization and too little on the development of meta-cognitive skills related to critical thinking and scientific literacy (Handelsman, et al, 2004; Hurd, 1997; Williams, Papierno, Makel, & Ceci, 2004). Glasson and Lalik (1993) argue that students need to reflect on, relate to, and examine concepts as they are presented as part of an active, constructive process. In fact, Thalheimer (2003) states that unless a student cognitively processes a question and participates in answering it (even if mentally), learning does not take place. This is unlikely to occur in traditional lecture classes where the constant stream of information leaves students scrambling to take accurate notes with little time to process questions and concepts.

The critics of introductory “gatekeeper” courses in STEM have argued that traditional lecture-based courses need to be transformed from pedantic, instructor-led classrooms to dynamic student-centered learning arenas (National Research Council [NRC], 2003; Wood, 2003). The movement supporting this transformation has gained widespread support from national funders including: the National Science Foundation, the National Science Resources Center, the National Science Teachers Association, the National Institutes of Health, and many scientific professional societies. The call for more active learning in introductory science courses has led to a burgeoning body of research known as the scholarship of teaching (Boyer, 1990), conducted by the research scientists teaching these courses, that investigates student outcomes related to these strategies.

Other research has examined predictors of students’ likelihood to complete a STEM degree (Seymour & Hewitt, 1997), the benefits of undergraduate research programs (Hunter et al., 2007), and the campus climate that science majors encounter during college (Chang, Eagan, Lin, & Hurtado, in press), yet scholars have not given as much attention to the climate of introductory courses that students encounter during their first year of college, particularly in the STEM context. Given that introductory STEM courses represent one of the first barriers students encounter along their STEM pathway, an examination of the relationship between students’ experiences in these courses and their self-reported engagement in the course is warranted, as a substantial proportion of intended science majors decide to leave STEM fields by the end of the first year of college (Chang, Cerna, Han, & Saenz, 2008).

Using a sequential, explanatory mixed methods approach, this study draws from quantitative survey data from 73 introductory STEM courses across 15 colleges and universities in combination with qualitative data collected from focus groups with students enrolled in these courses at eight of these colleges to examine the learning strategies and pedagogical practices that best relate to students' self-reported academic engagement. With this research design, we aim not only to examine the predictive power of specific learning strategies and classroom contexts that relate to STEM students' engagement in introductory courses but also nuance these findings with students' narrative experiences of being enrolled in these courses.

The Importance of Academic Engagement

The literature has defined academic engagement in both specific and broad terms. Svanum and Bigatti (2009) measured course engagement as attendance in lectures, course preparation, and review session attendance. By contrast, Larose, Robinson, Roy, & Legault (1998) conceptualized engagement simply as collaboration with students. In conceptualizing this study, we draw from a more specific operationalization of engagement promoted by Handelsman, Briggs, Sullivan, and Tower (2005), who define course engagement as interaction with course content both inside and outside the classroom. Handelsman et al. (2005) use items related to students' frequency of participating in class and interacting with faculty during office hours to define their participation engagement factor.

Academic engagement can, in and of itself, serve as an outcome in the classroom, and it has also been used as an intermediate outcome to predict some broader measure of student success. Academically engaged students have an increased likelihood of persisting beyond the first year of college (Nelson Laird, Chen, & Kuh, 2008; Pascarella, Salisbury, & Blaich, 2011). Additionally, Handelsman et al. (2005) linked academic engagement with higher end-of-course grades, as students who participated more in class and sought out faculty during office hours tended to end their courses with significantly higher levels of achievement. The link between academic engagement and student achievement and persistence, particularly in the case of STEM undergraduate education (Seymour & Hewitt, 1997), underscores the importance of identifying the student behaviors and pedagogical techniques that encourage students' engagement in their introductory STEM courses.

Students, the Classroom Climate, and Academic Engagement

Rocca (2010) notes that academically engaged students demonstrate greater motivation, improve their critical thinking skills, and demonstrate gains in personal character; however, she notes that not all students feel as though they have the capacity to fully engage in the classroom. Weaver and Qi (2005) found that feelings of intimidation and inadequacy may prohibit students from participating in class. Similarly, a lack of confidence may discourage engaging in the class, particularly when that lack of confidence is tied with a lack of understanding of course content (Fassinger, 1995; Weaver & Qi, 2005). Rocca (2010) suggests that better preparation may help to increase students' confidence thereby indirectly improving their willingness to participate and engage in their course.

In addition to students' psychology regarding course engagement and their preparation for a given course, Mann and Robinson (2009) suggested that students' interest in a course may relate to their overall engagement. Specifically, Mann and Robinson (2009) found that students who reported being bored more often in class reported lower levels of engagement. These lower levels of participation in class resulted in significantly reduced levels of academic achievement in the course.

Students’ academic engagement may also be affected by their understanding of the social networks within an individual course or within their institution. Stanton-Salazar (2010) stresses the importance of social capital and the role of institution agents (in this case, faculty) in helping provide access to forms of support. Students may arrive at college not knowing whom or how to ask for help, and faculty, given their position of authority, have an obligation to help orient those students appropriately to increase their likelihood of success.

In providing access to institutional resources and socializing students, faculty also signal accessibility cues (Wilson, Wood, & Gaff, 1974), which indicate to students their openness to and availability for support. Crombie, Pike, Silverthorn, Jones, and Piccinin (2003) found that students who sensed that their instructors cared about them demonstrated increased levels of engagement in the course. Having mutual respect, which values students’ contributions and encourages participation and questions from students, provides for a more inviting classroom climate that engenders greater engagement among students (Crombie et al., 2003; Dallimore, Hertenstein, & Platt, 2004). West and Pearson (1994) found that validating students’ responses to questions and affirming students’ questions increased students’ willingness to participate and engage in class.

Active Learning Pedagogies

Although student confidence and classroom climate represent important considerations for increasing students’ engagement in introductory courses, critics of these courses have seized on the pedagogical techniques utilized by many faculty who teach introductory STEM courses. These critics contend that faculty who teach introductory STEM courses have demonstrated a reluctance to embrace active learning teaching strategies (NRC, 2003; Wood, 2003). Active learning is generally understood as any technique that promotes student engagement in the learning process (Prince, 2004). Chickering and Gamson (1987) argue that active learning techniques require students to write, think, and talk about their learning while simultaneously applying it to their own lives. At the undergraduate level, this may include a number of in- and out-of-class activities, such as team projects and peer reviews, that promote a deeper level of understanding (Chickering and Gamson, 1987). It is this active process of learning which Handelsman et al. (2004) note helps students to develop the habits of mind that drive science. The use of active learning strategies in introductory STEM courses is in fact growing. Some examples include “bookending” the lecture with questions that focus student discussion, incorporating student response systems, requiring group projects and presentations, implementing peer-led team learning, and introducing problem-based learning or case studies (Allen & Tanner, 2005). A number of researchers have tested these active learning strategies, often looking at satisfaction and course grades as outcomes and often reporting mixed results.

One active learning strategy that has been implemented and tested in numerous settings is the use of student response systems or “clickers.” Caldwell (2007) contends that the use of clickers may increase attendance and decrease course attrition. Clickers have the potential to increase students’ understanding of course content, as they provide immediate signals to the instructor that students have not fully grasped the concept from a lecture or demonstration; however, instructors also have to have an adaptive response with immediate feedback once they become aware of students’ difficulty in grasping concepts (Caldwell, 2007; Crossgrove & Curran, 2008). These devices also increase students’ attentiveness and alertness in class (Nagy-Shadman & Desrochers, 2008). Studies also suggest that students perform better on exam questions that were associated with clicker questions in class, noting that the additional time an instructor took to address students' mis-understanding or lack of understanding of a concept helped students to master that content (Freeman et al., 2007; Preszler, Dawe, Shuster, & Shuster, 2007). Other research, however, suggests that students who used clickers showed no difference in performance on exams when compared to those who did not use the clickers in class (Crossgrove & Curran, 2008). The authors note that they the instructors for these courses had introduced other active learning strategies in both "clicker" and "non-clicker" courses that may have masked some of the effects that clickers had on students' performance.

Collaborative and cooperative learning represents another active learning method that researchers have examined in the context of introductory science courses. Collaborative and cooperative learning strategies require students to work together, but Prince (2004) distinguishes the two based on the method of assessment; in cooperative learning, students are graded individually while collaborative learning techniques call for a group-based grade. Adding cooperative problem solving and student participation activities to class may result in increased learning gains and higher levels of conceptual understanding (Knight & Woods, 2005). Implementing cooperative quizzes may also increase individual test scores (Zeilik and Morris, 2004). This strategy, as implemented by Zeilik and Morris (2004), allows students to discuss their quiz results with cooperative instructor-assigned learning teams in order to debate the answers before retaking the quiz. Introductory courses with cooperative learning groups that require students to work together to solve problems may also decrease course failure rates (Peters, 2005).

Introductory courses that utilize active learning strategies also have found success with web-based pedagogy as a way to engage students. Web-based pedagogy typically combines in-class lectures with out-of-class web-enhanced activities and has become popular over the past decade with the introduction of programs such as WebCT, Blackboard, and eClassroom (McFarlin, 2008). McFarlin uses the term “hybrid” to describe a course that offers 50% of the course content via traditional methods and 50% via the web. In comparing the outcomes of a hybrid course versus a traditional course, McFarlin found that exam grades and final course grades were significantly higher in the hybrid course. Students enrolled in a web-based interactive biology course at Rensselaer Polytechnic Institute also showed significant learning gains compared to those in a traditional course (McDaniel, Lister, Hanna, & Roy, 2007), yet the variety of teaching strategies used in the course make it difficult to isolate the cause of the learning gains. Students report that they enjoy the self-paced nature of the “hybrid” courses that incorporate web-based technology (McFarlin, 2008). Students also report that they enjoy using web-based technology for accessing course materials and interacting with their peers and instructors (Smith, Stewart, Shields, Hayes-Klosteridis, Robinson, and Yuan, 2005). In addition to allowing students the opportunity to engage with the material, peers, and instructors on a regular basis, Lockman, Gaasch, Borges, Ehlo, and Smith (2008) argue that WebCT is powerful because it provides students with immediate feedback on course modules and web-based exams. Students have also reported that they find virtual labs beneficial and believe virtual labs enhance their learning (Weisman, 2010).

Other active learning strategies include Just in Time Teaching, Peer-Led Team Learning, workshops, inquiry labs, and Problem-based Learning (Smith et al., 2005). The majority of the research, however, has been conducted in one or two classrooms at one institution by the instructors responsible for implementing these strategies. This is problematic for two reasons: (1) it is difficult to generalize findings based on one setting and (2) there is an inherent bias on the part of the researcher who is testing a method in her own course. Additionally, a majority of the research has been quantitative in nature with data collected via surveys and course evaluations. The present study addresses these limitations through the use of a mixed-methods approach across multiple classrooms and institutions. We have collected both quantitative and qualitative data at multiple institutions in hopes of reporting more generalizable findings enhanced by thick descriptions and nuanced explorations of engagement in introductory STEM classrooms.

Methodology

To address issues of engagement in introductory STEM classrooms, we utilize a mixed methods approach, more particularly a sequential explanatory mixed methods design, which consisted of collecting, analyzing, and integrating both quantitative and qualitative data during the research process (Creswell, 2005). This approach was taken, as neither quantitative nor qualitative methods were solely sufficient to capture the breadth and depth of student experience across multiple introductory STEM classrooms. When used in proper combination, quantitative and qualitative methods can complement each other and provide a more complete picture of the research problem (Green, Caracelli, and Graham, 1989; Johnson and Turner, 2003; Tashakkori and Teddlie, 1998). The quantitative data were collected first, preliminarily analyzed, and used to inform the selection of institutional sites for qualitative data collection. The results of the quantitative and qualitative phases were then more fully integrated (Creswell et al., 2003) during the analysis of findings and discussion, as the quantitative data and results provided a general picture of students' engagement, while the qualitative data refined and explained those statistical results by exploring the participants' views regarding their introductory classroom experience in more depth (see Fig. 1 for a diagram of the mixed methods sequential explanatory design procedures of the study). This mixed method design not only enhances explanation but also provides an opportunity for cross-validation of findings across techniques and across multiple institutions. This enhances generalizability of the findings while also maintaining an emphasis on contextual differences.

---Place Figure 1 about here---

Quantitative Design

Sample. The quantitative data for this study come from three surveys conducted during the spring of 2010: a pre- and post-survey of students in introductory STEM courses and a one-time survey of faculty teaching these introductory STEM courses. In the fall of 2010, researchers at UCLA's Higher Education Research Institute (HERI) identified 15 campuses to participate in a study of introductory STEM courses funded by the National Institutes of Health (NIH) through the American Recovery and Reinvestment Act (ARRA) of 2009. These campuses varied by institutional control, size, selectivity, minority-serving status (i.e., historically Black colleges and universities and Hispanic-Serving institutions), geographic region, and Carnegie classification.

Within each campus, researchers at HERI worked with administrators to identify introductory science, technology, engineering, and mathematics courses. A total of 81 separate courses composed the classroom sample, and the number of courses selected within each institution ranged from one to 18, with the average institution having five courses. These introductory courses spanned several disciplines and included such courses as calculus, pre-calculus, cell biology, introduction to design, introduction to computer science, introduction to physics, and general chemistry, among others. After identifying introductory STEM courses within each institution, HERI researchers emailed all students enrolled in these selected courses with an invitation to participate in an online survey. This initial survey, administered at the beginning of the academic term, requested information on students' pre-college preparation, pre-college experiences, background characteristics, and educational and career plans. Two weeks prior to the end of the academic term, we invited all students in these introductory courses to complete a follow-up survey, which post-tested career and educational aspirations and inquired about students' experiences inside and outside the context of their introductory course, their perceptions of faculty members' pedagogical style, and scientific habits of mind. Students received a $10 gift card for completing each survey. In total, 3,205 students completed both surveys, which provided for a longitudinal response rate of 42.1%.

In addition to the student surveys, we conducted a survey of all faculty teaching these 81 introductory STEM courses. The faculty survey requested information regarding faculty members' pedagogical styles in their introductory courses, their expectations of students, their perceptions of students' preparation, and issues of faculty workload. Faculty members received a $100 gift card for completing the survey, and the response rate for the faculty survey was 90.1%.

After deleting cases with missing data on the outcome and demographic characteristics and deleting students in courses where faculty did not complete a survey, the final analytic sample for this study includes 2,873 students in 73 introductory STEM courses across 15 colleges and universities. A majority of the student sample identified as White (52%), and 61% of students were women. Nearly half (42%) of students aspired to earn a medical degree, and 21% of students wanted to earn a Ph.D. or an Ed.D. Approximately 75% of students reported majoring in a STEM discipline. Table 1 provides descriptive statistics for all variables included in the analysis.

---Place Table 1 about here---

Variables. The dependent variable in the quantitative analyses represents the extent to which students reported being academically engaged in their introductory STEM course. Seven items compose the factor of academic engagement: frequency with which students asked questions in class, discussed course grades or assignments with the instructor, attended professor's office hours, participated in class discussions, tutored other students in their introductory STEM course, reviewed class material before it was covered, and attended review or help sessions to enhance understanding of course content. Each of these items represents the behaviors of students who strive for excellence in learning science and are the activities of successful students. Table 2 provides the factor loadings for an academic engagement construct, which had a Cronbach's alpha of 0.80.

---Place Table 2 about here---

To predict variation across students in their reported level of academic engagement in their introductory STEM course, we account for a number of student-level predictors. We control for race (White compared to non-White), gender, and pre-college academic preparation. The analyses examine the predictive power of aspiring to a medical degree (compared to any other degree), several of students' self-rated abilities, and the extent to which students asked high school teachers for advice outside the classroom on students' academic engagement. Among course and college experiences, the model examines the relationship between academic engagement and the frequency students sought tutoring, attended supplemental instruction sessions, perceptions of the course structure, and attitudes regarding the climate within the course.

To account for variation across classrooms, we include several course-level variables collected from the faculty survey. The level-2 model includes faculty perceptions of the climate they perpetuate in their classroom, their goals for undergraduate education, and dummy variables representing whether faculty have earned tenure or are on the tenure track (compared to their colleagues who are not on the tenure track). Lastly, because we examine classrooms across different types of institutions we account for variation across institutions in a level-3 model that includes two institutional variables: institutional control and whether the institution is a historically Black college or university (HBCU). Appendix A includes all of the variables and their coding schemes.

Analyses. Before using multivariate statistical techniques to analyze the data, we first weighted the data to adjust for non-response bias and accounted for cases with missing data. To adjust for non-response bias, we weighted the data by race, gender, and class standing, all of which were collected for the population of students enrolled in our selected introductory STEM courses within each institution. We then used logistic regression to determine the probability of responding to both surveys for each student originally enrolled in the introductory course. The weight given to each student was the inverse of the probability of responding to both surveys. Thus, a student with a 33% probability of responding to both surveys received a weight of 3.

To account for missing data, we relied on the expectation maximization (EM) algorithm for all ordinal and continuous student-level variables excluding the dependent variable. For student respondents with missing data on dichotomous variables or the dependent variable, we used listwise deletion of cases. The vast majority of variables had fewer than 5% of cases with missing data, and composite SAT score had the highest proportion of missing data at 12.1%. The EM algorithm relies on maximum likelihood techniques to impute missing values when variables have a small proportion of missing data (Allison, 2002; McLachlan & Krishnan, 1997), and thus this method provides for a more robust process of handling missing data than mean replacement or listwise deletion (McLachlan & Krishnan, 1997).

After accounting for missing data and weighting the data for non-response bias, we began descriptive and multivariate analyses of the data. The quantitative data represent a three-stage nested design, as students are clustered within classrooms which are clustered within institutions. Given the clustered nature of the data and the continuous outcome variable, we use a three-level hierarchical linear model (HLM). HLM represents the most appropriate statistical technique when analyzing multi-level, clustered data, as this method accounts for the homogeneity of errors with groups (i.e., classrooms and institutions); additionally, using HLM helps researchers to avoid making a Type I statistical error (Raudenbush & Bryk, 2002).

To justify the use of HLM, the outcome variable must differ significantly across groups. For this study, we determined the extent of variation in the students' self-reported academic engagement across classrooms and institutions by running a fully unconditional model (Raudenbush & Bryk, 2002). The fully unconditional model produced estimates of the intra-class correlation, or the extent to which academic engagement significant varied across classrooms and across institutions. These estimates suggested that 3.1% of and 4.1% of the variance in academic engagement was attributable to differences across classrooms and institutions, respectively. Given our interest in pedagogical differences and issues of classroom climates, we proceeded with an HLM analysis using a three-level model.

Qualitative Design

In the second, qualitative phase, we purposefully selected institutions based upon their high rates of participation in our quantitative survey and the resultant evidence of higher amounts of classroom innovation occurring on each campus. In sum, forty-one focus groups were conducted over a five-month time span, from October 2010 to February 2011, with 241 student participants from eight universities across the United States: two Hispanic serving institutions

(HSI), one historically Black college/university (HBCU), and five predominantly White institutions (PWI). The sample included 14% African Americans, 54% Whites, 8% Latino/as, 21% Asian Americans, and 3% Native American; 62% were women.

The student focus groups consisted of students either currently enrolled in introductory STEM courses or students who had completed these courses and participated in our quantitative data collection in spring 2010. We asked students to describe their experiences in introductory STEM courses through a series of nine main questions and corresponding probes, centering around student motivation, course structure, learning, instruction, and assessment, allowing their responses to dictate the order with which we asked the questions.

Focus group interviews, ranging from 60 to 90 minutes, were conducted with 2 to 10 participants per session, and averaged five focus groups per campus. We utilized a semi-structured interview technique that allowed us to respond "to the situation at hand, to the emerging worldview of the respondent, and to new ideas on the topic" (Merriam, 1998). Maxwell (2005) suggests that this technique increases the "internal validity and contextual understanding and is particularly useful in revealing the processes that led to specific outcomes" (p. 80). Prior to the interviews, participants were asked to complete a brief biographical questionnaire, which gathered data on a range of relevant background characteristics (e.g., demographic information, educational attainment, and research experience). All interviews were digitally recorded, transcribed verbatim by a professional transcription company, checked for accuracy, and loaded into NVivo8 qualitative software.

In order to develop the coding architecture utilized in NVivo, each transcript was open coded by examining the raw data and identifying salient themes supported by the text. This constant comparative approach followed an inductive process of narrowing from particular (text segments) to larger themes while allowing the researcher to attempt "to 'saturate' the categories—to look for instances that represent the category and to continue looking until the new information does not provide further insight into the category" (Creswell, 2008, pp. 150-151). Our team of six researchers each read transcripts from two institutions, gathering and comparing themes across focus groups and institutions, which also enabled analytical triangulation (Patton, 2002). Once we felt that we had reached saturation in generating themes, we developed several iterations of coding schemes, wherein codes were created, expanded, defined, and refined. These categories/themes in the raw data were then labeled as "nodes." Six researchers thematically coded three randomly-selected sections of text and inter-coder reliability ratings consistently ranged from between 80-85 percent (Miles & Huberman, 1994). Following inter-coder reliability exercises, the coding was re-validated and we were able to add new codes and sub-codes where necessary. Once the coding structure was finalized, we utilized 22 primary nodes, 114 secondary nodes, and 14 tertiary nodes in NVivo8. The data selected were stored there under the node and the link to the full record was maintained. Once these bins of relevant data were created, we re-read the data repeatedly in order to solidify our understanding and see connections amongst the categories. Queries were run linking participant attributes with coding references. In reporting qualitative findings through students' words we include the institutional descriptors of PWI, HSI, or HBCU and teaching vs. research institution as we had only 1 HBCU and 1 HSI in our qualitative sample and the instruction in those introductory classrooms closely resembles that taking place at the smaller, teaching institutions. These teaching institutions represent comprehensive universities as opposed to research/doctoral universities. We feel that these descriptors are sufficient in representing the institutional setting, while differentiating on the basis of substantial differences between research institutions and teaching institutions.

Findings

In order to understand the experiences of students in introductory STEM courses, we offer composite representations of idealized “Gatekeeper professors,” “Engaged STEM professors” and “Engaged STEM students.” Sewn together from the words of students in our focus groups, we provide a narrative context regarding what has been and what is possible while realizing that most professors and students are complex combinations of positive and negative traits.

Composite Representations

The "Gatekeeper” professor. The term “gatekeeper” has been used to describe introductory STEM courses, but perhaps the analogy would be better suited in describing the instructor of introductory STEM courses. Gatekeeper professors lecture straight from a PowerPoint while students hang on their every word. It is nearly impossible to write down everything the gatekeeper says, let alone process the information, so students make the personal decision to listen, in hopes of understanding, or to take notes, in hopes of making sense of it later. A brave student may ask the gatekeeper to slow down, but most students know that the gatekeeper frowns upon students who ask him to slow down or repeat what has already been said. Students may have a better chance of processing the information in lecture if they had an outline to follow, but the gatekeeper does not believe in posting the PowerPoint lecture online because this may discourage students from coming to class. Students will not answer questions in class because the gatekeeper has already trained them that lectures are for “listening,” not for interacting.

Additionally, gatekeeper professors disregard individual learning styles because they are so focused on conveying the abundance of information that must be passed on to students who are worthy of passing through the gates.. As they profess, their expectation is that students can and should understand the content at his level. The gatekeeper may scare students from the major by continuously making content feel intimidating and difficult to learn. Students who learn through visual stimulation or tactile methods often struggle with the gatekeeper's style of lecture. Students may wonder if all STEM courses will lack the engagement and real world application that they need to learn the material. Others get discouraged because they spend so much out-of-class time trying to understand the concepts that the gatekeeper failed to explain clearly during lecture. Beyond lecture, the gatekeeper is inaccessible through office hours and e-mail, making it difficult for students to get additional help. Clearly there is a disconnect between the gatekeeper's style of teaching and the learning style of students. There must be a better way to engage students in introductory STEM courses.

The "Engaging" professor. The "gatekeeper" is a well known image that will continue to transcend higher education classrooms despite a call for more engaging pedagogy in the STEM disciplines. The image of an "engaging" professor, however, has begun to emerge at some of the most innovative institutions. The engaging professor uses strategies that encourage active learning, cooperation among students, and student-faculty contact (Chickering & Gamson, 1987). A collaborative learning environment is fostered by the engaging professor, both in- and out-of-class. After engaging professors explain a concept, for example, the way blood flows through the heart, they will ask students to get into groups of four and explain the concept to each other. Walking around the room allows the engaging professor to gauge the general level of understanding while students personally evaluate their own ability to explain the way blood flows through the heart. Out-of-class group projects also foster a collaborative spirit amongst students while encouraging students to process the material beyond the lecture. Through course websites, the engaging professor provides students with a one-stop shop for downloading PowerPoints to be used in lecture, podcasts from previous lectures, video clips that can enhance understanding of difficult topics, and discussion groups that encourage additional collaboration amongst students. The night before a quiz, students utilize the web-based discussion groups to ask each other questions while the engaged professor continues to facilitate discussions from the comfort of home.

The engaging professor also facilitates student excitement in the classroom through humor, enthusiasm, and practical application. The excitement and passion for the subject is contagious, and students begin to have fun and learn in an environment that fosters interest in STEM disciplines. Studying disease suddenly becomes more enjoyable because the dense content is applied to a real world problem that students can relate to, such as cancer or HIV. Beyond real world applications, the engaging professor uses physical objects, including Legos, puppets, play guns, and balloons, to model the concepts in class. This helps students to understand subjects such as physics, microbiology, and organic chemistry because the abstract concept is now connected to a three dimensional demonstration. Beyond the classroom, the engaging professor is highly accessible to students and encourages them to participate in additional learning opportunities provided by the university. The engaging professor responds to e-mails, encourages students to stop by her office, and provides additional assistance at supplemental instruction (SI) workshops. There is no limit to the things the engaging professor will do to get students motivated in their STEM major and excited about the possibilities of pursuing a STEM career.

The “Engaged” student. In introductory STEM courses, an engaged student is often, but not always, pre-med and looking to bolster her knowledge base for the MCAT or more advanced science courses, as well as to fulfill major requirements. This student is very focused on getting high grades while also mastering the material. The engaged student chooses professors strategically, looking for engaging and thorough teachers by utilizing Rate My Professor or through advice from upper classmen. Armed with strong pre-college preparation, this student enters these courses with eagerness and a strong interest in science, which is evidenced by commonly seeking out professors after class, attending office hours, and emailing them regularly.

The engaged student is incredibly resourceful, taking advantage of multiple opportunities to enhance learning. Regular attendance is commonplace at class-related supplemental instruction or recitations. This student has strong study skills and often meets with her peers in self-initiated study groups where they re-teach one another content and prepare for tests together. Tutors and tutoring centers provide additional opportunities for the engaged student to work with more advanced students or graduate students to clarify understanding. This student takes advantage of any available opportunities to collaborate with professors and build relationships with them by participating in undergraduate research or by becoming an SI instructor or TA. Assuming professors are somewhat engaging, the engaged student's experience in introductory STEM courses typically furthers interest in the topic and dedication to science.

Academic Engagement in STEM Classrooms

These composite narratives combine many of the qualities of engaged students and professors that significantly predict students' level of academic engagement in the introductory STEM classroom. Quantitative results provide general information about the relationship between student learning strategies, faculty attitudes and characteristics, pedagogical techniques, and student level engagement in introductory STEM courses and are enhanced by qualitative findings that provide more detail about student perspectives about their own and faculty behavior. The findings will be integrated throughout the results section. Table 3 provides a full accounting of the HLM results analyzing students' academic engagement. Among the student-level variables, the findings suggest that White and students of color do not significantly differ in their reported level of academic engagement in introductory STEM courses. Likewise, we detect no significant differences across gender. Only one of the four pre-college preparation variables remained significant to the final model: high school chemistry grade. Students who reported earning higher grades in high school chemistry also reported themselves to be significantly more academically engaged in their introductory college STEM courses; however, high school biology grade, SAT composite score, and earning college math credits did not significantly predict students' academic engagement in introductory STEM courses. Freshmen students reported significantly higher levels of academic engagement in introductory courses than students who had been in college for a longer period of time, which suggests that students who wait to fulfill STEM course requirements are less likely to be engaged.

---Place Table 3 about here---

Although background characteristics and pre-college preparation largely lacked significance in predicting students' engagement in introductory STEM courses, the quantitative findings suggest that students who felt excited about learning new concepts tended to report significantly higher levels of engagement. Initially, we examined students' interest in taking introductory courses, and taking the course for personal interest predicted higher levels of engagement; however, when we added students' sense of excitement about learning new concepts to the model, this variable accounted for the predictive power of the personal interest variable. This finding suggests that a genuine interest in learning, rather than simply striving to make a certain grade in the course, is significantly related to students' engagement in their studies. Although was quite rare for students to express this sentiment in focus groups, Marie is one such student with a genuine interest in learning:

> I'm realizing for the first time, maybe, that with these classes, like, I want my knowledge to be furthered. Like, I mean, I -- obviously want to get an A, but like, in my biology class he [the professor] was saying like, you know, 'You don't necessarily have to read this chapter for the test, there's some material you don't necessarily need to know for the test, but you can if you want,' and I found myself like, 'I want to read this chapter', you know? Like, I want to know, like, just to further my knowledge, to know the material better, and I think that -- I dunno, just measuring success is like, furthering knowledge and enriching that, I guess. (PWI, teaching institution)

Marie is willing to go above and beyond to enrich her own knowledge and learn for learning's sake; in this way she is highly engaged in her introductory courses. Yet, as previously stated, very few students expressed this genuine interest in learning and resultant engagement.

The Pre-med Phenomenon – Career Motivation for Engagement

When asked why they enrolled in introductory STEM courses, most students simply said that they needed to fulfill a requirement for their major. We found that pre-med students, however, are an exception. The quantitative findings indicate that those students who came to college with aspirations for medical school tended to report being significantly more academically engaged than their peers with other educational goals. Given the competitive nature of medical school admissions, students with plans for medical school likely recognize the need to do as well as possible in their science courses, which explains these students' increased levels of academic engagement.

The pre-med students involved in our focus groups had a keen awareness of the importance of introductory STEM courses and described needing to excel in order to form a strong foundational science knowledge to utilize in upper level courses, to be prepared for their planned scientific careers, and to do well on the MCAT. Rocco, a pre-med student, discusses his approach to studying in introductory STEM courses:

> I would rather learn what's in the book, even if it's not on the test. I'd rather learn that good information because it will help me out –I feel like it will help me out in the future, whether it's like –whether it's just for that bigger picture of it, like a better understanding of it, or like I'm going to need that information in my career, and take an MCAT. (PWI, teaching institution)

Rocco is willing to go learn material beyond what might be on the test in order to build a stronger overall science knowledge base. His statement is indicative of the approach to learning taken by the majority of the pre-meds interviewed and their high level of engagement with the course and class content. While these students' learning is often motivated by a desire to be prepared for future steps along the STEM pipeline, that does not mean that grades are unimportant or that competition does not exist. In fact, the HLM results indicate that in these introductory courses, students who thought of themselves as more competitive than their peers tended to report significantly higher levels of academic engagement, even after controlling for respondents' educational aspirations.

Although qualitatively we did not find substantial data regarding students' internal sense of competition, the interaction of engagement and competition was evidenced in other ways. Students who were particularly engaged in their courses, who were striving to earn an A, most often described feeling a sense of competition in their classes, either between themselves and pre-meds or amongst pre-meds, as evidenced by student interaction. As Marian says, it becomes "survival of the fittest".

> When I know that someone is pre-med, I mean, I can be friends with the person, but there's always gonna be, if I know …that there is an internship for a hospital, I'm not gonna tell the person next to me that. I'm gonna get it, I'm gonna find out, I am, yes, sometimes I am very selfish when it comes to that. Because it's – survival of the fittest. (HSI, teaching institution)

This attitude extends not only to more weighty opportunities like internships but also into more fundamental daily interactions, even to something as simple as answering one another's questions. Many students described either being unwilling to help their fellow students or encountering students unwilling to help others for fear of boosting other students' grades, and being edged out of their A.

> Well, in the back of your mind you're always just like – I mean, especially for I guess pre-med students. In the back of your mind you're always like, 'I have to make a higher GPA. I have to make higher grades,' 'cuz it all comes down to who's gonna have the highest grades and have the highest credentials. So I mean, even though you do stick up for one another sometimes, still in the back of your mind you're always just like, 'Well, you know, I do have to be better than him'. (Oscar, PWI, teaching institution)

It is clear that these students are engaged, working hard, and trying to outdo one another. This extreme sense of competition not only affects the climate inside the courses but also occasionally extends to interactions outside the classroom, where students who do not view themselves as particularly competitive feel uncomfortable interacting with their competitive peers and are not able to engage fully in collaborative learning, as Celina explains.

> I don't really, really like to do study groups because I feel like it's just them trying to compete and them trying to show me how much they know versus how much I know, and I know some people do like study groups. It does help them, but because they're competitive, and naturally I'm not really a competitive person so I usually study by myself. (PWI, teaching institution)

Celina's conception of other students "showing how much they know" or Oscar's notion of "having to be better than" speak to the ways in which the climate in these courses set by faculty sometimes limit a fundamental mechanism of student engagement: genuine collaboration.

Collaboration with Peers and Use of Interventions

Quantitatively, collaboration and studying with peers predicted students' level of engagement in the course. This finding suggests that more active learning on the part of the students enhances their connection and interest in the class. Many students in the focus groups described the favorable influence of a collaborative environment in their introductory courses, which often encouraged them to engage more fully in the course. As suggested by Stewart's words below, students were often more inclined to get involved in supplemental instruction and/or tutoring sessions if they had other students who joined them:

> I know in math, I usually try to find people around me, like, in pre-Calculus I had a small group of people that sat around me in class. And you know, if I didn't get something, it was easier to turn to them and see if any of them understood it. And if they did, then I could ask them for help, and it was a lot easier than trying to ask the professor, and then you know — you don't wanna study alone for something you don't get, so it's nice to have a small group of people to go with you to like the Q lab or SI sessions and things. So that way, you know, if one person doesn't get it then the other people can help him. If the [SI Leader] is not being as helpful as they could be, then there are other people to help back that up. (HSI, research institution)

In considering use of supplemental instruction and/or tutoring sessions, our quantitative data suggests that students who spend more time with tutors, either on-campus or off-campus in a private setting, tend to have significantly higher levels of academic engagement than peers who seek out tutoring less frequently. Similarly, respondents who attended more supplemental instruction sessions reported being significantly more academically engaged in their introductory courses. We know from our qualitative data that some institutions in our sample required these sessions of students whereas other campuses made supplemental instruction optional. The quantitative data suggest that, regardless of why students attend these sessions, more frequent attendance provided for a greater level of engagement within the course. A more nuanced view of students' use of tutoring and/or SI sessions reveals that students often sought this additional instruction when they felt that their classroom-based instruction was insufficient for them to properly learn the material.

> I absolutely didn't understand anything the professors were telling me. So, I finally broke down and went to the tutors, the second time I had to retake Chemistry II, and it helped so much. The way they were explaining things, they actually got the models and show me how the molecules break, and came together, or they would test me. They wouldn't

> give me the answer, they'd make me work for the answer. I did so much better in that class. He [the instructor] just talked, and tried to explain it like, as if he was teaching in class again, so. I chose to go to tutors before I'd ever go to the professors. (Cadence, PWI, teaching institution)

Cadence was not able to learn from her “Gatekeeper Professors” so she took an additional step and ‘broke down’ by going to the tutoring center. Through the use of tutors, who utilized active learning strategies like hands on models and problem based learning, she was able to understand the concepts and more fully engage with the content of her courses. Cadence’s issue with her professor is representative of many other students who found lecture-based, teacher-centered courses problematic.

Faculty Pedagogy and Engagement

In fact, among students’ perceptions of course structure, our quantitative findings suggest that students who described the course as predominantly lecture tended to report significantly less engagement in the course. These sentiments were echoed throughout the focus groups, as many students described the mind-numbing lectures that they regularly sat through, often feeling unengaged and unenthusiastic about the course. Talia describes it well when she says:

> In a lot of my biology courses, the professor just sort of talks at me, and I’m like – I don’t feel, like, as engaged or just, well, I feel like, in those courses there is a lot more memorization only, which is why I don’t get as much out of them because I’m very hands-on. Like, if I’m doing something in the class, I can be like, grasp that I’m understanding it, but if the professor is just talking at me, writing stuff on the board, expecting me to write it down, like that’s doing nothing, and then I’m completely disengaged in class. (Talia, PWI, teaching institution)

By contrast, quantitative analyses revealed that sensing a greater proportion of time devoted to class discussion or group work seemed to enhance students’ frequency of engaging with course content and connecting with faculty inside and outside the classroom. Not only did the focus groups confirm this finding but they also enabled us to nuance our discussion of which innovative pedagogical techniques, students found to be most engaging. Below we present exemplars representing the three innovations students discussed most often: group work, clickers, and web based pedagogy.

> For my class now he gives us like the first five minutes of class, like he'll assign us groups and then say just discuss the homework…just getting in groups, sometimes explaining it as a student to another student who's had the same like, who's just read the same chapter as you or something who maybe understands it a little better can be a lot, can be more helpful than even talking to a professor who's not sure what you're confused about or something like that. So I think group work in class can really be, can really be effective. (Bernadette, PWI, teaching institution)

> In physics, we had—he would put up a question on the board, or on the slide projector thing, and we used the clickers to click in an answer. And then he'd use that to gauge where he needed to go, which direction to continue the class. And that was really helpful I think because sometimes if the class clearly didn't grasp the concept, he would go back and elaborate on it. (Lori, PWI, teaching institution)

> In biology we used this website called mastering biology and it has like videos and questions and quizzes online and different like videos of the cells. Then you can have videos of it being used in real life with the organisms themselves so it gives you like different perspectives. It was really interesting. (Holly, PWI, teaching institution)

Students described these pedagogical techniques as "effective," "helpful," "different perspectives," and "interesting" – all words indicating the positive effects of these active learning strategies on students' engagement and that describe behaviors that define the "Engaging Professor." Yet while the majority of students preferred the aforementioned teaching approaches and recognized their benefits, a small number of students in our focus groups, primarily those who were pre-med, indicated that they prefer STEM courses to be mostly lecture, since there is so much information to be covered. Even when lecture was the primary vehicle for conveying course content, the professor's attitude, knowledge base, enthusiasm for the subject, and ability to explain the content clearly were all important characteristics for determining student engagement. These qualitative findings suggest that the lecture itself may not be the problem, but the style of lecture combined with the professor's own engagement profoundly impact student engagement. Here Harlow describes the importance of professors' enthusiasm for the subject matter they are teaching.

> Well, I think there's some professors, too, who get real excited during lectures. They're very excited and just passionate about the subject. When that happens, I feel it's easier for you to become more excited about it and enjoy the class and come to class and be like, 'Oh, this is fun. This is great.' This professor enjoys what they're talking about, so it's easier to learn from them. It's not just dull and boring. Those are usually the professors that have group activities or other things that are built in that allow for a more well-rounded way to learn than just lecture. (PWI, teaching institution)

Accessibilty Cues and Engagement

While professors' teaching strategies, attitudes, and enthusiasm were influential factors of classroom climate shaping students' engagement in introductory classrooms, it is also critical for students to feel comfortable asking questions, as our quantitative results indicate that students who felt comfortable asking questions in class reported being significantly more engaged in their introductory STEM courses. Likewise, having a level of comfort in asking questions in class suggests that it is more than just students' self-confidence in speaking up in class, as we account for their self-rated communication ability and initiative taking as well as their prior behaviors in asking for help; instead, the positive connection between engagement and students' comfort in asking questions in class likely connects more to the overall climate students perceive in class – that professors not only welcome questions and participation but in fact encourage such behavior. Students in the focus groups also discussed the importance of professors providing a supportive environment in STEM introductory classrooms. Although some students said they felt uncomfortable asking questions in class, others stated that their professors created an environment that was friendly and playful, which made it easier to ask questions. This is highlighted by Carter's words:

> On the other hand, I have my [biology] class and it's like 200 kids, and I don't have a problem asking a question in that class because he's just – he's cool about it, you know,

> it's really – it's not – it's not like it's a – he has – I don't know, the attitude that there's not a stupid question and he's really neat about it. It's like he's heard them all, you know, and he'll make jokes about stuff and things like that and he really has a really playful attitude. (PWI, teaching institution)

The connection between academic engagement and students' perception of classroom climate becomes further underscored when considering some of the course-level variables in the level-2 model of the quantitative analysis. For example, significantly higher levels of academic engagement were reported in classrooms where faculty agreed with the statement that "there is no such thing as a question that is too elementary" (Table 3). By signaling to students that the classroom represents a safe environment where any question can be raised, faculty encourage students to become more engaged in and curious about course content. Even in a situation where the professor initially seems intimidating, students may become more engaged after receiving a small signal from the professor, as illustrated by Bella's words.

> My Chemistry teacher, at first he looked scary cause he was almost like kind of yelling. But I guess that's how he is. But there was this one time like, everybody was scared to answer this one question. And then he was like, 'Why not?' And then one student was like, 'Cause I don't understand,' and then he was like, 'There you go. There you go. Just ask me what it is,' and then he gave her like five points to her exam. So, like, after that we were all like, 'Hey Professor, how do you do this?'…he was like, really open. (Bella, HSI, research institution)

Beyond encouraging students to ask questions, the classroom climate may be further enhanced when professors provide immediate feedback and make themselves accessible to students. Findings across classrooms show that students who received feedback that helped them to learn and improve reported being significantly more engaged in their introductory STEM courses (see Table 3). Students discussed the value of such immediate feedback as they described the value of clickers and other student response systems.

By contrast, findings indicate that students had significantly lower levels of academic engagement in classrooms where faculty reported a lack of time to provide individualized attention to students, or who agreed that it is primarily up to students to be successful in their introductory courses (Table 3). Together these findings underscore the accessibility cues that students sense from faculty; thus, if students perceive faculty to be uncaring, unengaged, or unavailable to help them succeed in learning, they may disengage from the course. This finding is further highlighted by Tilly's words:

> There are some situations where you can reach out to a professor, but there are some where you can't. You can suggest to get a study session going for a certain course, but if that professor doesn't have enough time or doesn't have time available for, to meet up with everyone, then it's like a wasted attempt. And after awhile, once you keep attempting and attempting to get those study sessions going and that professor is continuously unavailable, it kinda like replays in your head. Okay, well, I might as well just not even try with that professor. Just do it on my own as I've been doing. (Tilly, HBCU, teaching institution)

When professors indicate they are available, students are more likely to ask questions, attend office hours, and participate in out-of-class review sessions with the professor. Our findings highlight the importance of the professor creating a welcoming classroom environment in order to increase student engagement.

Empowered and Resourceful Students

While many students expect faculty to provide support, encouragement, and space for mastering course content, students must still play a significant role in their own learning. It is those students who embrace their own agency, and actively seek out their professors, that prove to be the most engaged. Indeed, considering students' self-ratings and educational aspirations, the quantitative results indicate that students who conceived themselves to be more resourceful at the beginning of the academic term, as indicated by higher self-ratings on communication skills, initiative-taking, and ability to know when and whom to ask for help, reported being significantly more academically engaged in their introductory STEM courses. Likewise, respondents who reported more frequently asking a teacher for advice or help outside of class in high school tended to have higher levels of academic engagement in college introductory STEM courses. Given that the outcome for the quantitative portion of the study includes items related to asking questions in class, it is not surprising that students with better communication skills, initiative taking, and an understanding of how to be resourceful with instructors significantly and positively relate to students' reported level of academic engagement in their introductory STEM course.

We are able to describe the numerous ways in which engaged students enacted this resourcefulness in terms of interacting with faculty members. Some describe interactions as simple and straightforward as asking a question in class, but, nevertheless, they show the initiative to raise their hand and ask; however, as Marshall states, many students are reluctant.

> I don't usually ask questions just to ask questions, the professors will ask, 'Does everyone understand? Does anyone have any questions?' and then at that point I'm like, 'I do not know what he's talking about at all', so I'll ask a question. I think a lot of different people do that but some people just don't really. I think sometimes professors like want you to ask questions..because I think it helps them understand like instead of just going through and lecturing all day. (Marshall, PWI, teaching institution)

Other students take a different approach and seek professors outside of class, utilizing their resourcefulness to actively engage in their own learning. There were three typical ways in which students sought this additional communication with their professors: after class, during office hours, and through email.

> I knew it was gonna be hard, and I'm just trying to push through it, so --I've been taking advantage of his office hours, and he's -- he's interested, he really loves the subject, and he really helps me when I go to his office hours. (Ruby, PWI, teaching institution)

> But the strategy I always used because I was shy, so I just waited 'til the end of the class**.** Then I would go to the professor. And you know, always if you keep it going enough, at the end of the class and ask a question all the time, then the professor just sort of gets, you know, to know you. And it sort of makes you sort of develop a good relationship. (Shareen, HSI, research institution)

> So, I try to e-mail 'em, and most of 'em are pretty good at getting back e-mails, and sometimes they'll work around your schedule too. 'Cuz like the teacher that I had, they always wanted you to know so if you need any extra help, they're there…If you really want to get help, they will help you. (Sky, PWI, teaching institution)

In these ways, many students are able to actively engage with their professors and course content. Through these interactions, students are able to increase their understanding of course content, build relationships with their professors, and get the help that they needed by being resourceful and learning how to acquire their professors' support.

Institutional Differences

Aside from these student and classroom level findings, we included just two institutional predictors in the level-3 model, as we have just 15 institutions in the analysis. The findings suggest no differences in average academic engagement between private and public institutions. However, students who attended HBCUs reported significantly higher average levels of academic engagement in introductory STEM courses compared to their peers at predominantly White institutions (PWI). The positive benefit on academic engagement from attending an HBCU connects to prior research that suggests faculty at HBCUs provide a more supportive learning environment that encourages academic success (Allen, 1992; Nelson Laird et al., 2007). Although we did not see differences in the qualitative data between students who attended HBCU's and other institutions, this finding makes sense, as teaching institutions are more similar to HBCU's in their supportive atmosphere and faculty priorities. We did however see substantial qualitative differences in the experiences of students attending teaching institutions versus research institutions. These students' words speak not only to the professors, but to differences overall in how science is taught at some institutions.

> For organic chemistry it's a very large lecture hall. There's about 300 to 500 people and the professor will just lecture for about an hour about whatever topic was that he had prepared. That's the one where we have the huge lecture halls and you don't get to know

> your professors. I'm used to small classes with like 30 students where I can talk to the professor and get to know the professor compared to chemistry where we have three exams and no homework. (Ryan, PWI, research institution)

> I feel like as a whole at our university, we all like genuinely want to do well and I don't think anybody really like tries to hinder anybody else in that way. Then also for my class, like my teacher on the first day of class, he's like we're going to climb this mountain together. Like no one's going to be left behind. You guys are going to help each other out and like that's how we kind of treated the whole class. (Sarai, PWI, teaching institution)

These students' words illuminate the stark distinctions between learning from a "Gatekeeper" and learning from an "Engaged Professor" and underscore the different learning environments in which they operate. By highlighting significant findings regarding student engagement across multiple contexts, we hope to have painted a more nuanced picture of what engagement looks like in introductory STEM classrooms. Yet we still need to consider what we can do to change things for students like Ryan who remain invisible to faculty in large classrooms. If introductory STEM instruction continues to foster a "gatekeeper" climate, delivering information instead of engaging students, we risk losing aspiring scientists, like Qianna, who describes her departure from her STEM major:

> I do not like enjoy the class [biology], so that's why I'm switching majors…the professor just, it's not clicking, so I'm having to do a lot of outside work on my own, with just trying to teach myself through like tutors and the books. So maybe had I had a different professor who explained things differently 'cuz I'm also more of a visual person instead of just lecture. (PWI, teaching institution)

If Qianna had Holly's instructor who used web-based visualizations for life science teaching, or Sarai's professor who promised to "climb the mountain" together, she may have been more likely to continue to major in biology.

Conclusion/Implications

With increased interest in STEM among entering students, the U.S. is at a critical crossroads in terms of its opportunity to improve the production of science degrees four-year colleges and universities. Indeed, students' intentions to major in biomedical and behavioral sciences have nearly doubled in the last 15 years, engineering fields have regained student interest in recent years (Pryor, et.al, 2007), and there is an ever increasing national focus on STEM education. These positive developments may be for naught, as a substantial proportion of intended science majors decide to leave STEM fields by the end of the first year of college (Chang, et.al, 2008), and often because of their experiences in introductory STEM courses. Even if we significantly raised the level of student preparation in high school science, it is likely that many students may be discouraged from majoring in STEM fields without significant engagement in college introductory coursework. Such academic engagement has as much to do with the engagement behaviors and attitudes of faculty who teach these courses as it has to do with motivated and resourceful students.

In examining students' engagement across multiple classrooms and institutions utilizing both quantitative and qualitative data, we are able to learn a great deal about engagement in introductory courses. The measure of academic engagement we employed emphasizes striving for excellence, as articulated in Essential Learning Outcomes for personal responsibility associated with learning (AAC&U, 2002). Some students not only enter better prepared, the most engaged students are also more resourceful (i.e., possess strong communication skills, initiative taking, and the ability to know when/whom to ask for help). Engaged students not only ask questions in class, they also interact with their professors after class, during office hours, and via email. They utilize all available resources, including supplemental instruction (whether it's required or not), tutors, and review sessions. Faculty, academic counselors, and peers can encourage and empower students to be more resourceful and make the most use of opportunities to learn.

Pre-med students are more engaged than their peers in introductory classrooms because they are motivated by a range of factors, most commonly a strong desire to master content in order to build a firm foundation for upper level courses or for future careers, as well as in preparation for the MCAT. High grades are most important for admission to medical school. However, pre-meds' behavior can also increase competitiveness and undermine other students' success in introductory courses unless faculty change the climate by shifting from gatekeeping strategies where few are expected to do well to engaging practices that ensures more students can succeed in these courses. Students who are genuinely interested in course content and learning for the sake of learning are also more engaged than their peers.

We found that engaged students in STEM courses regularly collaborate with their peers, whether in formal or informal study groups, or working homework problems. They turn to their peers for help and alternative ways of understanding course content. Instructors also encourage this collaboration through group projects and assignments that require teamwork.

Professors play an equally important role in sustaining engagement in science through accessibility cues. Students are more engaged when professors create an atmosphere that promotes asking questions, where there is no such thing as a question that is too elementary. Professors' demeanor and attitude are especially important in making students feel comfortable in class. Most importantly, when professors utilize active learning pedagogies, like clickers or strategies that offer immediate feedback, adapt their teaching to ensure more students have grasped the material, or use web based pedagogies that make the most of new technologies for illustrating concepts, students are more engaged in courses. However, students are less engaged in teacher-centered, lecture-based classes, where they must figure things out on their own and faculty do not check for student understanding except via exams, forcing students to retake the class if they are committed to a STEM major

Most STEM faculty prize students who go the extra mile to learn material, demonstrate intellectual curiosity, and are engaged in class. Their own attitudes and behaviors are critical in producing more of these students and in the process of transitioning their role from "gatekeepers" to "engaged faculty." Although multiple authors have stated that few faculty are familiar with the science education literature and unaware of the data and analyses that demonstrate the effectiveness of active learning techniques (Handelsman et al, 2004; Labov, 2004), the burgeoning body of literature in this area can no longer be ignored. While we recognize that faculty face considerable demands besides teaching and that it takes considerable time to develop an active learning approach, more and more introductory STEM instructors are embracing the call to enact change in their classrooms, as this approach is truly vital to student success. Administrators need to support their faculty in curriculum redesign and adoption of innovative teaching techniques through professional development both on and off campus, aimed at re-shaping classrooms into engaging spaces.

As faculty and administrators search for new ways to engage students and enhance learning environments, institutional researchers can be a prime source of knowledge for campus constituencies by helping to identify gateway courses that are problematic for students. This involves not only assessing student behaviors but also faculty behaviors across classrooms and sections. At the same time, institutional researchers should continue to think about various methods for gathering data related to introductory STEM classrooms, including the use of mixed methods strategies that truly enable thorough, rich exploration. Finally, such assessments should result in feedback to faculty so that they have a greater context for understanding student success strategies influenced by their own behaviors, and faculty who participated in this mixed method study received reports about their classrooms. We demonstrated that multiple contexts differed significantly, indicating that classroom and institution-wide transformation is necessary if we are to make progress in increasing STEM degree attainments nationally.

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Appendix A

Table of Measures

Variable	Coding
Dependent Variable	
Academic Engagement	Factor composed of seven items: frequency with which students asked questions in class, discussed course grades or assignments with the instructor, attended professor's office hours, participated in class discussions, tutored other students in their introductory STEM course, reviewed class material before it was covered, and attended review or help sessions to enhance understanding of course content
Institutional Variables	
Control: Public	0=Public, 1=Private
HBCU	0=No, 1=Yes
Course-Level Variables	
Faculty course goal: Use technology to effectively engage students	1=strongly disagree to 4=strongly agree
Faculty agreement: In my classroom, there is no such thing as a question that is too elementary	1=strongly disagree to 4=strongly agree
Faculty agreement: I feel it is primarily up to students whether they succeed in this course	1=strongly disagree to 4=strongly agree
Faculty agreement: There is not enough time available to give every student individualized attention	1=strongly disagree to 4=strongly agree
Tenure status: Tenured (reference group: not on tenure track)	0=No, 1=Yes
Tenure status: Not tenure, on tenure track (reference group: not on tenure track)	0=No, 1=Yes
Student-Level Variables	
Sex: Female	0=No, 1=Yes
Race: White (reference group: non-White)	0=No, 1=Yes
SAT composite score	Continuous, range 400-1600

HS biology grade	0=F to 4=A
HS chemistry grade	0=F to 4=A
Earned college math credits in high school	0=No, 1=Yes
Freshman (reference group: non freshman)	0=No, 1=Yes
Degree aspiration: Medical doctorate (reference group: all other aspirations)	0=No, 1=Yes
Frequency: Asked a teacher for advice or help outside of class in HS	1=Never to 3=Frequently
Self-rating: Communication skills	1=Lowest 10% to 5=Highest 10%
Self-rating: Initiative-taking	1=Lowest 10% to 5=Highest 10%
Self-rating: Ability to know when and whom to ask for help	1=Lowest 10% to 5=Highest 10%
Self-rating: Competitiveness	1=Lowest 10% to 5=Highest 10%
Agreement: Faculty gave students written feedback on their performance or progress in the course	1=strongly disagree to 4=strongly agree
Frequency: Sought tutoring from a campus office or program	1=Never to 5=Very often
Frequency: Sought a professional (off-campus) tutor	1=Never to 5=Very often
Frequency: Attended supplemental instruction sections	1=Never to 5=Very often
Frequency: Felt excited about learning new concepts	1=Never to 5=Very often
Frequency: Collaborated with other students in this course	1=Never to 5=Very often
Frequency: Studied with other students in this course	1=0 to 13=Greater than 10 hours
Proportion of class time devoted to lecture	1=0% to 7=100%
Proportion of class time devoted to class discussion	1=0% to 7=100%
Proportion of class time devoted to group work	1=0% to 7=100%
Agreement: Felt my hard work was reflected in my grades	1=strongly disagree to 4=strongly agree
Agreement: Felt comfortable asking questions in class	1=strongly disagree to 4=strongly agree
Agreement: I was motivated to try hard on course assignments and exams	1=strongly disagree to 4=strongly agree
Agreement: I received feedback that helped me learn and improve	1=strongly disagree to 4=strongly agree

Figure 1. Visual Model of Mixed-Methods Design Procedures
(Adapted from Ivankova, Creswell, & Stick, 2006)

Phase	**Procedure**	**Product**
QUANTITATIVE Data Collection	• Institutional and course identification • Survey administration • Registrar's data collection	• Quantitative data on innovations in 73 classrooms
Connecting Quantitative and Qualitative Phases	• Developing qualitative interview protocol • Purposefully selecting institutions based on innovation and participation	• Participant cases • Faculty cases • Institutional cases
Qualitative Data Collection	• Focus groups with 241 student participants • Demographic questionnaire	• 2000 pages of transcription • Participant background questionnaires
QUANTITATIVE Analysis	• Descriptive analyses • Factor analysis • Multivariate analyses	• Factors • Correlations • Multivariate statistics
Qualitative Analysis	• Coding and thematic analysis • NVivo8 qualitative software data sorting	• NVivo coding architecture • Coded transcriptions • Casebook linking demographic data with interview data
Integration of the Quantitative and Qualitative Results	• Cross validation of findings by technique • Significant quantitative themes are nuanced by qualitative data and integrated	• Results • Discussion • Future Research

Table 1
Descriptive Statistics of Variables Included in the HLM Analysis

	Mean	S.D.	Min.	Max
Dependent Variable				
Academic Engagement	0.00	1.00	-1.60	2.62
Institutional Variables				
Control: Public	0.57	0.51	0.00	1.00
HBCU	0.14	0.36	0.00	1.00
Course-Level Variables				
Faculty course goal: Use technology to effectively engage students	3.16	0.88	1.00	4.00
Faculty agreement: In my classroom, there is no such thing as a question that is too elementary	3.52	0.82	1.00	4.00
Faculty agreement: I feel it is primarily up to students whether they succeed in this course	3.00	0.72	1.00	4.00
Faculty agreement: There is not enough time available to give every student individualized attention	3.05	1.00	1.00	4.00
Tenure status: Tenured (reference group: not on tenure track)	0.42	0.50	0.00	1.00
Tenure status: Not tenure, on tenure track (reference group: not on tenure track)	0.13	0.34	0.00	1.00
Student-Level Variables				
Sex: Female	0.61	0.48	0.00	1.00
Race: White (reference group: non-White)	0.52	0.50	0.00	1.00
SAT composite score	1258.06	154.72	400.00	1600.00
HS biology grade	3.73	0.51	1.00	4.00
HS chemistry grade	3.65	0.57	0.00	4.00
Earned college math credits in high school	0.21	0.41	0.00	1.00
Freshman (reference group: non freshman)	0.60	0.49	0.00	1.00
Degree aspiration: Medical doctorate (reference group: all other aspirations)	0.42	0.49	0.00	1.00
Frequency: Asked a teacher for advice or help outside of class in HS	1.94	0.66	1.00	3.00
Self-rating: Communication skills	3.69	0.90	1.00	5.00
Self-rating: Initiative-taking	3.66	0.88	1.00	5.00

Self-rating: Ability to know when and whom to ask for help	3.63	0.89	1.00	5.00
Self-rating: Competitiveness	2.62	0.93	1.00	5.00
Agreement: Faculty gave students written feedback on their performance or progress in the course	2.59	0.98	1.00	4.00
Frequency: Sought tutoring from a campus office or program	2.26	1.41	1.00	5.00
Frequency: Sought a professional (off-campus) tutor	1.71	1.17	1.00	5.00
Frequency: Attended supplemental instruction sections	2.58	2.15	1.00	13.00
Frequency: Felt excited about learning new concepts	3.13	1.04	1.00	5.00
Frequency: Collaborated with other students in this course	2.95	1.12	1.00	5.00
Frequency: Studied with other students in this course	3.46	2.44	1.00	13.00
Proportion of class time devoted to lecture	5.84	1.16	1.00	7.00
Proportion of class time devoted to class discussion	2.48	1.56	1.00	7.00
Proportion of class time devoted to group work	1.95	1.32	1.00	7.00
Agreement: Felt my hard work was reflected in my grades	2.68	0.84	1.00	4.00
Agreement: Felt comfortable asking questions in class	2.71	0.79	1.00	4.00
Agreement: I was motivated to try hard on course assignments and exams	3.07	0.74	1.00	4.00
Agreement: I received feedback that helped me learn and improve	2.62	0.77	1.00	4.00

Table 2
Factor Loadings for Academic Engagement

	Cronbach's Alpha	Factor Loading
Academic Engagement	0.80	
Asked questions in class		0.73
Discussed grades or assignments with the instructor		0.71
Attended my professor's office hours		0.69
Participated in class discussions		0.59
Tutored other students in this class		0.57
Reviewed class material before it was covered		0.53
Attended review or help sessions to enhance understanding of the content of the course		0.46

Note: The scale for each item ranged from 1=Never to 5=Very Often.

Table 3
HLM Results Predicting Students' Academic Engagement

	Coef.	S.E.	Sig.
Institution-Level Variables			
Control: Public	0.10	0.09	
HBCU	0.32	0.14	*
Course-Level Variables			
Faculty course goal: Use technology to effectively engage students	0.03	0.02	
Faculty agreement: In my classroom, there is no such thing as a question that is too elementary	0.05	0.02	*
Faculty agreement: I feel it is primarily up to students whether they succeed in this course	-0.06	0.02	**
Faculty agreement: There is not enough time available to give every student individualized attention	-0.03	0.01	*
Tenure status: Tenured (reference group: not on tenure track)	0.13	0.04	***
Tenure status: Not tenured, on tenure track (reference group: not on tenure track)	0.10	0.06	
Student-Level Variables			
Sex: Female	-0.02	0.02	
Race: White (reference group: non-White)	0.04	0.03	
SAT composite score	0.01	0.01	
HS biology grade	-0.03	0.03	
HS chemistry grade	0.05	0.02	*
Earned college math credits in high school	0.04	0.03	
Freshman (reference group: non freshman)	0.09	0.03	***
Degree aspiration: Medical doctorate (reference group: all other aspirations)	0.05	0.02	*
Frequency: Asked a teacher for advice or help outside of class in HS	0.11	0.02	***
Self-rating: Communication skills	0.04	0.02	*
Self-rating: Initiative-taking	0.04	0.02	*
Self-rating: Ability to know when and whom to ask for help	0.07	0.02	***
Self-rating: Competitiveness	0.03	0.01	*
Agreement: Faculty gave students written feedback on their performance or progress in the course	0.05	0.01	***
Frequency: Sought tutoring from a campus office or program	0.17	0.01	***
Frequency: Sought a professional (off-campus) tutor	0.21	0.01	***
Frequency: Attended supplemental instruction sections	0.03	0.01	***
Frequency: Felt excited about learning new concepts	0.09	0.01	***
Frequency: Collaborated with other students in this course	0.03	0.01	*
Frequency: Studied with other students in this course	0.04	0.01	***

Proportion of class time devoted to lecture	-0.04	0.01	***
Proportion of class time devoted to class discussion	0.02	0.01	*
Proportion of class time devoted to group work	0.03	0.01	**
Agreement: Felt my hard work was reflected in my grades	-0.04	0.01	*
Agreement: Felt comfortable asking questions in class	0.20	0.02	***
Agreement: I was motivated to try hard on course assignments and exams	0.05	0.02	**
Agreement: I received feedback that helped me learn and improve	0.05	0.02	**
Model Statistics			
Level-1 variance explained	0.56		
Level-2 variance explained	0.96		
Level-3 variance explained	0.60		
Overall variance explained	0.58		

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$