INNOVATIVE IMMERSION APPROACH TO RETENTION OF AFRICAN-AMERICAN 1ST YEAR CHEMICAL ENGINEERS

A Thesis

presented to

the Faculty of the Graduate School

at the University of Missouri-Columbia

In Partial Fulfillment

Of the Requirement fot the Degree

Master of Science

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by

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MAY 2020

INNOVATIVE IMMERSION APPROACH TO RETENTION OF AFRICAN-AMERICAN 1ST YEAR CHEMICAL ENGINEERS

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MASTER OF SCIENCE IN CHEMICAL ENGINEERING

The Department of Biomedical, Biological & Chemical Engineering

“And so, lifting as we climb, onward and upward we go, struggling and striving, and hoping that the buds and blossoms of our desires will burst into glorious fruition ere long.”

-- Mary Church Terrell

Acknowledgement

My Advisors & Contributors

Dr. Patrick Pinhero

Dr. Terrell R. Morton

Adrian L. Haley

First Supporters

Detric Lavern Cathey

Johnette Marie Lever

Emma Lever

Henry & Karen Spate

My Sisters & Friends

Deidre Cathey

Kalen Spate

Collise Dennis

My Brothers & Motivation

Daniel Nwachuku

Eric D, Mays

Ikenna Egbosimba

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Roger Lutcher IV

Dijon Lowery

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Abstract

Abstract

Students that identify as Black[1], chemical engineers, and 1st-year undergraduates face unique circumstances along with perspectives that have not been assessed in depth. This pilot study aims to highlight the challenges facing 1st-year African-American students, within the bounds of their experiences during their introductory chemical engineering course and overall interactions within a Chemical Engineering Department at a Predominately White Institution (PWI). The emphasis on 1st-year students is that this group faces the largest retraction of enrollment across disciplines and the students studied possess intersecting identities noted to foster an "at-risk" retention history. Chemical engineering is a specialized major in itself and faces unique retention challenges; studies specific to retention in chemical engineering separate from engineering as a whole are limited. African American engineering retention characteristics and phenomena are an emerging field; insight specific to chemical engineering 1st-year students are not heavily reflected in the literature. The literature and my own findings show cultural[2] barriers that hinder African-American students from perceiving the department as a nurturing and inclusive environment. This pilot study looks to bridge the institutional divides to gain an understanding of a population overlooked, as an effort to build a base for future work specifically examining and addressing Black students' experiences in chemical engineering.

[1] Within the study I will be using the term Black and African-American as interchangeable terms. An African-American is an individual with American family background as American of African and especially of black African descent. Black individuals are not limited to national identity. Black can include Jamaicans who do not consider themselves to be African American but Caribbean Americans.[54]

[2] Organizational culture is a system of shared assumptions, values, and beliefs, which governs how people behave in organizations. [55]

Chapter 1

Introduction

1.1 Background and Impact

Engineering, as a field and profession, is a principle driving force for technological innovations; it also seeks to determine the environmental impact of various societies. Chemical engineering is a specialized division within engineering. Due to their broad education, practicing chemical engineers work across a wide range of industries in varying capacities. A conventionally defined chemical engineer uses their expertise to design, operate, and manage chemical processing and manufacturing in economically competitive, industrial-scale plants that maximize value-added processes while minimizing cost. Chemical engineers (ChEs) have unique academic preparation that is designed to educate and train students to develop competency, which overlaps with other engineering disciplines. The educational program of interests for this study possesses special emphasis on chemical processes, which permits chemical engineering graduates to be employed in an array of diverse commercial sectors beyond the chemical industry. These include materials, healthcare, electronics, energy, and many others. [2] The wide spectrum of employment options available to chemical engineers magnifies their societal impact. As such, they drive advances in several industrial sectors and manage their environmental impact. [5]

Diversity is a crucial agent in fostering innovation. As Andrew Hargadon noted in his *Harvard Business Press*: “by allowing the cross-fertilization of ideas across different applications by forging connections between individuals, teams, or firms with diverse experience and resources, innovation can be sustained at remarkable rates.”[13] Innovation is rarely the result of a lone inventive genius or an isolated culturally-homogeneous group. Chemical Engineering is a field, which faces a noticeable lack of diversity. In 2014, The American Chemical Society (ACS), a preeminent professional organization consisting of collegiate and professional chemists and chemical engineers, stated “African-Americans only constitute two percent of their membership.” [2] Even the National Society of Black Engineers (NSBE)—a very well respected professional organization predominantly composed of African-American collegiate and professional engineers—has only a 10 percent Chemical Engineering membership [2].

1.2 Problem Statement

“It is generally accepted that the most successful and productive problem-solving teams that demonstrate they can effectively assess a set of conditions, develop an effective and well-balanced plan for resolution, and lastly. execute and manage this plan in a timely manner, are teams where inclusivity and diversity exist.”[48] Currently the lack of African-American chemical engineers present influences the overall ability of engineering teams to reach their maximum production potential. In noting this lack of representation of Black engineers overall, scholars have begun to examine the factors that influence Black engineers collegiate experiences and persistence to ascertain what prompts Black students to pursue, remain, or leave an engineering degree. [41]Taking a similar approach, this study seeks to explore Black student engagement specifically within Chemical engineering. The focus of the present study is to 1) identify factors that encourage or discourage African-American retention at the initial stage of declaring chemical engineering as their academic major; 2) examine whether a more inclusive introductory course in chemical engineering could assist in retaining more African-American students with an interest in the subject, and; 3) provide recommendations that would support African American students' retention and graduation in the undergraduate chemical engineering program at the University of Missouri.

The reality is the United States needs more engineers. [19] African-Americans are an underserved and uptapped potential within this segment of the American population. Only 2% of Black freshmen enroll in engineering programs and chemical engineering majors make up less than 10% of that 2%. The pipeline of capable Black students is not empty but broken. Black students are not properly stimulated, directed to, or supported in engineering studies and careers. In order to mitigate and repair the faults in the chemical engineering pipeline at the University of Missouri, the institution of focus, it is first important to capture the perceptions, experiences, and impacts of the University of Missouri Chemical Engineering Department on African-American students enrolled in its program. This task will provide data that can potentially be used to immediately cap losses of students and ensure that barriers are removed or mitigated to enhance matriculation and retention efforts of capable African-American chemical engineering students. Once the present environment is inclusive, the Chemical Engineering program can begin to address their connection to the Black community as a whole, i.e., more effective recruitment of top African-American high school students with an interest in chemistry, science, mathematics, and technology. Again, it is important to emphasize that the shortages of Black people in chemical engineering are not due to the lack of available, competent students; but simply, it is that those students follow career paths that have been historically more welcoming. [24]

1.2.1 Representation

Failing to retain African-Americans in undergraduate chemical engineering prompts their underrepresentation in all post-graduate chemical engineering pathways [28]. There is a reduction in representation for African-Americans at every degree level given lower proportional enrollments that are possibly due to their undergraduate experiences. African Americans earned 4.8% and 4.2% of master's and doctoral degrees in engineering, respectively, which are both less than the 5% bachelor degree attainment figures [28]. These trends are noted among professional careers. For example, African-Americans only account for 2.6% of full tenure-track faculty [28] with approximately 2% working within an engineering field. The pipeline of prospective African-Americans into Chemical Engineering shows apparent pitfalls at every level of progression, further perpetuating the cycle of low proportional enrollment. Research notes that a disproportionate amount of African-Americans tend to select occupations and pursue careers in which they had contact with successful role models [7, 10, 26]. The scarcity of Black chemical engineer role models perpetuates a cycle of discouraging Black students from earning chemical engineering degrees. This lack of Black chemical engineering role models could further prompt a dissociation for Black students in their perceived ability to be successful in this field.

Within the context of The University of Missouri (Mizzou), during my undergraduate career, there was a significant dearth of Black students in ChE preventing the formulation of functional African-American peer-to-peer groups or a mentoring structure to assist African-American students with navigating the major. Many individuals, including administrators and faculty, tended to take the moderate stance of “not seeing color” among student ranks, failing to recognize and account for the needs of a diverse student body. Employing color-blind neutrality does not establish nor promote an inclusive and empathetic environment, instead, it unintentionally connotes apathy. Attending to representation not only accounts for Black students’ numerical presence but it also helps unpack their perceived sense of belonging within the major and field. Initiatives at predominantly white institutions (PWIs) to combat these limitations include providing nurturing experiences and attempting to build a sense of community with meaningful and productive bonds. For example, Clemson University, a state institution that closely mirrors the University of Missouri when looking at their ratio of the Black population to Black student enrollment, broaches the top 20 institutions for graduating African-American engineers and is among the top 10 PWIs in graduating African-American engineers. [6] Clemson addressed their challenges in representation by formulating their *Programs for Educational Enrichment and Retention* (PEER). These programs work to place incoming students from underrepresented groups into support groups that assist in their collegiate transition. This PEER program offers several services, including employing upper-class students (i.e., juniors and seniors) to serve as mentors to the freshmen and sophomores. Research investigating representation acknowledges that most norms and cultures within classrooms and workplaces were developed to the benefit of a single group. In acknowledging that most practices were formed in the exclusion of Black students, scholars and practitioners are better equipped with formulating new practices to better support African-Americans.

1.3 Purpose of the Study

Given the noted underrepresentation of Black students within Chemical Engineering, as constituted by the lack of diversity articulated above, this study seeks to examine the experiences of 1st-year Black students enrolled in their introductory Chemical Engineering course at the University of Missouri. Currently, only one (1) of the 11 chemical engineering program faculty (i.e., 9.1%) identifies as African-American. A recent reorganization at the college-level to form the University of Missouri's Biomedical, Biological, and Chemical Engineering (BBCE) Department, which increased faculty in the unit to over 35 members, dilutes the African-American tenured/tenure-track representation to 2.9% overall. This is further diluted at the college-level, where only one (1) of the University of Missouri's College of Engineering out of 140 tenured/tenure-track faculty (0.7%) identifies as African-American. To put this in context, these seven prospective chemical engineer degree aspirants have one individual in the entire university to look to as a faculty role model.

1.3.1 Research Questions

In considering the existing research, this study attends to the experiences of Black students in Chemical Engineering. Noting representation accounts for the ways in which numerical presence informs Black students' perceptions and experiences, this prompts deeper investigations into aspects such as the culture of Chemical Engineering and how it positively or negatively impacts an African-American's perception of and experience within the major[37] including the relationship between their current experiences and their future endeavors. [39] Recognizing the significance of these concepts, with limited research examining them specifically within Chemical Engineering, the following research questions guide this study:

1. What is the culture of Mizzou and the larger field of Chemical Engineering?
2. What are African-Americans sense of belonging within these cultures?
3. What are the career outlook and opportunities for African-American students?

To address these questions, I employ case study qualitative research methods, utilizing observations and interviews to ascertain Black students perceptions of the Chemical Engineering department and the initiatives provided that they see as beneficial to them. I analyze this data using the phenomenological variant of ecological systems theory (PVEST) conceptual framework, attending to the effects culture has on these individuals.

Chapter 2: Literature Review and Conceptual Framework

In unpacking the research on Black students' experiences in engineering, I am provide a brief overview of the key components discussed: persistence and retention, culture, and their various outlook and opportunities. I subsequently follow with the PVEST conceptual framework, indicating how it will inform my analysis of Black student experiences in their introductory chemical engineering course.

2.1 Persistence and Retention

Engineering disciplines have similar trends in retention. The greatest losses in enrollment are at two definitive points: during or following their introductory course and during their initial core concept or foundation course.[21] In the University of Missouri ChE, these two introductory and foundation courses are labeled *CH_ENG 1000/1000H* and *Mass and Energy Balance (CH_ENG 2225/2225H)*. The focus of this research project is to detect and implement intervention points and strategies within the introductory course (CH ENG 1000) and determine their effectiveness in retaining African-American students within the ChE program. Retention within the study is derived from the six-year graduation rate. Persistence rates are the percentage of students that return following their first year. Retention rates have shown a strong correlation between race and gender. Retention rates in engineering by race/ethnicity, nationally, is 66.5% for Asian-American students, 59.7% for White students, 44.4% for Hispanic/LatinX students, and 38.3% for African-American students. Even within a "weed out" engineering culture (e.g. practice to purge out seemingly inferior students), overall, engineering students tend to persist at a higher rate than other majors. The persistence rate in engineering majors ranked first nationally with

92.8% [11]. Studies have shown that persistence correlated strongly with pre-college preparation regarding the level of high school math and science courses available to students and their SAT/ACT scores [11]. Statistics show African-Americans and other underrepresented groups (e.g., Hispanics and Native Americans) have lower persistence rates [11, 21]. When extracting and solely focusing on high-achieving underrepresented students, the deviation in persistence rates is minimum, and race alone is not a reliable, predictive metric [11].

To further explore retention in engineering, I explore retention through the lenses of performance, perception, and exposure. I define each of these terms based upon meaning relevant to this study and existing research. Performance is the demonstration of the student's ability to obtain and apply technical knowledge. Performance contributes to attrition during the initial concept course traditionally taken during the sophomore year. Student performance is normally predicted by high school GPAs and ACT/SAT test score correlations [11]. The introductory ChE course at Mizzou introduces students to the major, and since students are usually within their first semester, topic difficulty is limited to high school level science given that all students may not have completed the necessary university level chemistry, math, and/or physics required to advance into the ChE core concept course (e.g., CH ENG 2225). Introductory course success is determined by the course's ability to convey information and its ability to fill educational inadequacy from the student's secondary education. Performance, from a student perspective, thus constitutes their ability to ascertain and demonstrate that they understand the knowledge provided. While performance is a key metric to ascertain in examining retention, this study primarily focuses on the exposure and perception aspects of retention.

Exposure references how students' exposure to the various fields of endeavor within Chemical engineering and Mizzou's Chemical Engineering department. Perception is students' view of the larger field of chemical engineering (i.e., how they see and understand roles and world of ChE professionals) and their belief of the personal opportunities they can obtain within ChE. In this study, I focus on the perception and exposure aspects for African-American students because even among high-achieving individuals that persist at the same rate as other groups, 62.5% of Black students face a six-year graduation rate compared to 94.8% of Asian Americans and 86.7% White students. I continue to isolate figures for high-achieving African-Americans to further highlight the phenomenon of Black retention losses with high-achieving Black students being retained at lower rates than other overall groups. [18]

Black student retention rates, overall, specific to the University of Missouri-Columbia, which is within the broader University of Missouri system, are noted through the institution's "equity rating" signified by scholars at the University of Southern California Race and Equity Center. In 2019, these scholars produced a first of its kind study that provided a "report card" that measured how well public colleges and universities are educating and graduating Black undergraduates [34]. The state of Missouri finished 46th among the 50 states. The ratings were given on a 4.0-grade point average style scaling equity index, where the state of Missouri scored a 1.68 with most of its universities within the study scoring near a 2.0 index. The University of Missouri-Columbia individually scored a 1.75 equity rating based on a 7.8% African-American student representation, which is 73% less than the state representation of African-Americans, 14.6% for the 18 to 24-year-old demographic. The other main factor contributing to the low score was the university-wide 55.8% African-American graduation rate compared to 69.1% overall graduation rate. In noting challenges with Black student retention, by attending to both existing research and statistics specific to Mizzou, this study seeks to unpack aspects that inform Black students' experiences in Chemical Engineering by examining their overall perceptions of and exposure within their introductory chemical engineering course.

2.2 Culture

In examining Black student experience in chemical engineering, a major point of analysis includes noting the strengths and characteristics of the chemical engineering department's culture. Culture is defined as the beliefs and values that exist within an organization perpetuated through the practices and mindsets of the staff; it is also based on the foreseen value of an individual's work, cyclically influencing individual attitudes and behaviors [36]. One way to attend to culture and its influence on Black student retention is to consider the differences in experiences and successes of Black students in STEM attending historically Black colleges and universities (HBCUs) compared to Predominantly White Institutions (PWIs). HBCUs have significantly fewer resources allocated to them when compared to PWIs, suggesting that the primary predictive figure for informing Black students' success in STEM is the culture generated by HBCUs. [27] HBCUs create an environment in which Black students can more closely develop a sense of belonging within STEM. [10, 31] PWIs, like the Mizzou, generate a culture that reflects that of the overall American society. [49] This culture is seen especially within the Chemical Engineering department, a field dominated by white male individuals.

The dominant culture of the United States as a whole is Euro-centric. The dominant culture of a PWI like Mizzou and its BBCE department favors White, male, non-first-generation students. Both the institution and its department's cultural values align with those whose identities fall within that specific archetype; even non-Black faculty of color exhibit a bias against Black students. [50 51 52] While all students face an adjustment period when transitioning from secondary to postsecondary education, individuals of the dominant culture (i.e., those whose values, practices, and beliefs effortlessly align with that of the values, practices, and beliefs of the postsecondary context) face challenges that are more than general progressions in maturity and ability. [10]

Diversity is currently an objective frequently discussed within the ChE field, but inclusion is not. Inclusivity acknowledges that diversity alone is not enough to engage underrepresented groups; without an inclusive environment, marginalized individuals are subjected to settings that are perceived as hostile, alienating, and isolating. Scholars who examine STEM culture as it relates to Black students describe the ways in which Black students' perceptions of their identities in relationship to STEM culture generates varying coping strategies for success. [39] These strategies include assimilation, accommodation, or resistance to the culture of STEM. At PWIs, African-Americans, in many cases go from learning environments where the leadership and peers reflect their own identity and culture (i.e., K-12 and communcal experiences), to spaces where they must evoke coping mechanisms (e.g., assimilation, accommodation, etc.) to fit within the culture perpetuated by of the college they attend.[40,41,42]

2.3 Outlook and Opportunities

The underrepresentation of Black students in undergraduate engineering programs prompt challenges for their experiences in professional careers. Aligning students' expressed inspirations and aspirations with the possibilities and outcomes of a STEM degree prompts a stronger sense of personal connection to STEM for underrepresented students. [43,44] Generating these efforts have the potential to increase the overall positive perception of an engineering major; highlighting the possible success following degree attainment may also serve as a tool to recruit and retain engineering students as it provides a clear indication that enduring undergraduate engineering experiences are worthwhile. While obtaining any engineering degree leads individuals to believe that they will maintain a more than comfortable middle-class lifestyle, high salary, and low unemployment [15], African-American chemical engineers do not receive those same benefits. The *Next America: Higher Education* project supported by the Bill and Melinda Gates revealed that African-Americans in high demand fields like engineering only fared slightly better than their liberal art degree counterparts; whereas others with engineering degrees (i.e., White and Asian) fared significantly better than their counterparts with liberal arts degrees. [14] African-American engineers face 10% unemployment rates when African American college students, overall, face a 12% unemployment rate.[14] Research suggests that the network disruption of not having role-models from similar backgrounds negatively influences the ability of African-Africans to be absorbed into the Chemical Engineering pipeline from K-12 to employment.[7,10,14]

2.3 Summary

The research discussed above highlights the current status of persistence and retention, the importance of culture in scholastic development, and the long term impact these topics have on the individual and system as a whole within engineering. With persistence rates not being the sole issue for Black students' continued engagement in engineering, the narrative that the problem in retention is solely because of the individual or a failure to assimilate is disrupted, lending credibility for examining failure within the overall system or context to provide adequate, inclusive support. Building an inclusive culture for those that are isolated and alienated is necessary. Existing research, through a systematic approach, is suggesting that retention issues are beacuse Black students are being placed in learning contexts that do not account for or include their culture and their perspectives.

Chapter 3: Methods

3.1 Conceptual Framework

I have adopted the Phenomenological Ecological Systems Theory (PVEST) conceptual framework to analyze the data gathered, supporting further discussion regarding 1st-year, Black students' perceptions and experiences in ChE at a PWI. [45]

PVEST is a conceptual framework focused on the integration of inter-subjective experience and their outcomes. PVEST describes the influence of positive or negative stimuli on an individuals identity development, attending to the individual's choices and reactions as a result of their experiencing of that stimuli. Such stimuli is contingent upon the individuals' demographic identities, the context in which they are operating, and the presence (or absence) of challenges and support mechanisms. All of this experience is nested within a broader ecological system, noting the impact and influence of various cultures (e.g., micro, meso, exo, macro) that influence the other. For example, the Macro culture represent societal perceptions, values, and understandings of Chemical Engineering and Black students. The Exo culture constitutes the University of Missouri-Columbia's values and beleifs. The Meso culture represents the College of Engineering with the Micro culture representing the Chemical Engineering major.

PVEST Concepts

1. Net Vulnerability level: a history of prior experiences and coping outcomes.
2. Net stress engagement: actual experience that challenges an individual's well-being.
3. Reactive coping methods: employed to resolve dissonance-producing situations.

4. Emergent identities: coping strategies are repeated, become stable, and combine with self-appraisal to form an identity.
5. Life-stage, specific coping outcomes: identity affects future behavior and outcomes (self-esteem, achievement, health, etc.)

Through PVEST, the students' conception of their Blackness not a new phenomenon and it shapes their ChE departmental experiences and perceptions. As such, students' racial identity as Black generates their net vulnerability given racism and stereotypes they have experienced and potentially will experience in the future. Their net stress engagement, or their daily interactions filled with either social supports or hassles they face, represent their engagements within their ChE major, including but not limited to their interactions with peers, faculty, and staff. Reactive coping constitutes the students' responses to their ChE engagements, detailing whether or not their response yields maladaptive or adaptive solutions to the stress faced within their environment. Stable coping responses are lasting personal identities and self-efficacy; how students see or associate themselves with ChE. Lastly, life stage outcomes detail whether or not adverse or productive relationships and developments occur given the students' overall engagements throughout the PVEST cycle. Each stage is co-dependently interacting with the previous and following stages.

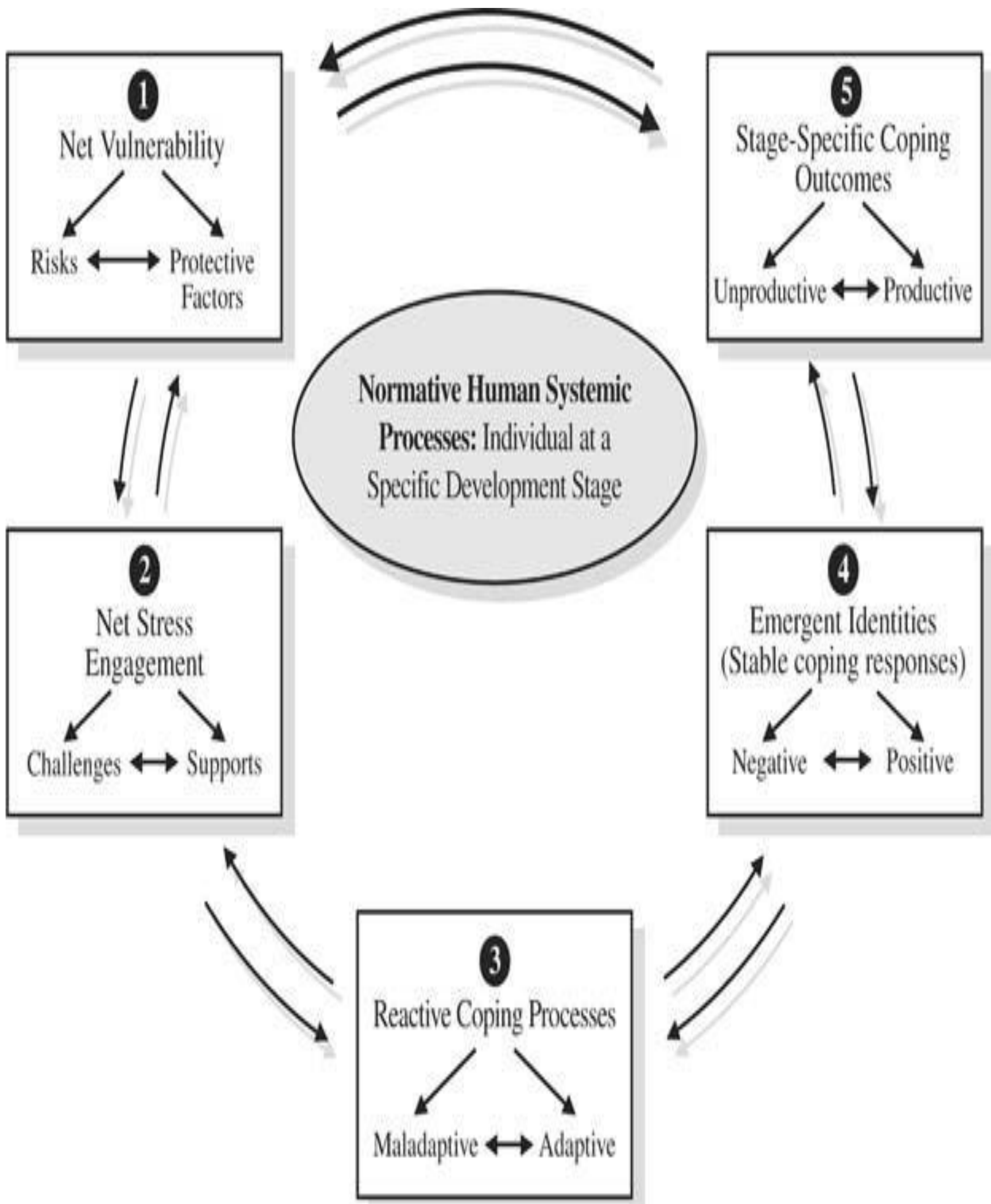

Figure 1: Graphic representing of PVEST cycle adapted from M.B. Spencer (2006) Phenomenology and Ecological Systems Theor: Development of Diverse Groups. In R. M. Lerner & W. Damon (Eds.), *Handbook of child psychology: Theoretical models of human development* (p. 829–893). John Wiley & Sons Inc.

3.2 Positionality

In recognizing my positionality and how it informs my understanding and examination of engineering culture [46], I come into this work bearing the identities of African-American, out of state resident, student-athlete, and second-generation college students. I also note that I maintain experiences in predominantly Black and predominantly White K-12 institutions. My identities and subsequent experiences prompt the desire to see progress made in the ChE department to create a better, inclusive culture as compared to the one I experienced in the 2014-2015 school year as a first-year student. The culture I faced during my first-year influenced my behavior throughout the program. This culture consisted of diverse individuals from many groups other than my own, who formed productive working groups that were mutually exclusive of outsiders (i.e., White students studied with White students and international students with students of the same nation of origin), which led to me to feeling isolated because there were no other Black students or people for me to associate with. The same option to surround myself with individuals similar to me was not available with the small demographic of Black students within the program, and the lack of inclusivity with the department at the peer level solidified that mindset. Aside from the culture of the department shaping my experience, I also had two successful and near age family members that were chemical engineering students at different PWIs that provided me with a sense of solidarity and support. As a student outside the dominant demographics, my transitional adjustments extended beyond the traditional maturation challenges and included identity-specific challenges (i.e., simple tasks like finding an appropriate barbershop) which informed my overall sense of belonging to the institutional and departmental community. I note tasks that seem mundane, like finding a barbershop, to demonstrate how culture, both from an individual-psychological perspective and a societal-anthropological perspective shapes and informs students' belonging and engagement across communities (i.e., personal, social, and academic) as previously noted. [47] My experience, thinking through an individual lens, was at first a failure to find a motivating and nurturing community specific to my endeavors. I took an individualistic approach to progress through the major by figuring out ways to succeed by myself with little outside help or input. I perceived others to have people who supported them; these factors contributed to my experienced isolation. Throughout this experience, I developed a sense of personal accountability and initiative, but I also had many challenges and frustrations with feeling as if I had to quickly understand course concepts from the instructor in order to be able to be successful. My experiences and subsequent decision-making processes mirrors that of many Black engineering students at PWIs. [42] My later success, once I was reconciled with the limitations of my isolation during my third year in the program (noting them as departmental failures rather than failures of my own accord), stemmed from developing a cohort of other students within my major who, though were not from my cultural background, were also not included in the dominant culture of the major (e.g., Asian, Middle-Eastern, and other international students).

3.2 Context

This study took place during the fall at the University of Missouri and focuses on the cohort of 1st-year chemical engineers. The original enrollment of the course was 58 total students with seven identifying as African-American.

3.3 Participant Description and Data

This study focused on the experiences of Black students in an introductory chemical engineering course where I served as a teaching assistant. The population, thus, constitutes the seven Black students enrolled in a Fall cohort. Data gathered in this study consists of interviews and researcher observations.

Seven interviews took place over the course of a 5-month timeline. These interviews focused on their ChE experiences and personal identity, with particular emphasis on how the experiences and identities interacted with one another. Specific information regarding the interview protocol and process is found within appendix 1d. Quota sampling was employed for the interview component of the study. [53] I decided to use quota sampling given the limited number of eligible participants present and my desire to protect students' identities. Three of the seven eligible students constitute the sample for this study; these three students were selected and interviewed due to the availability of scheduling of students as well as due to time constraints given the length of the interviews and the necessary transcription process. The three participant's interviews provide an adequate representation of the identities of the various Black student population found within the class. To protect their anonymity, throughout this study, these students are identified as student 1(a Black female student), student 2 (a Black female student), and student 3 (a Black male student).

Researcher observations took place over a 5-month period covering the student's first semester. To conduct these observations, I utilized a protocol that focused on the students' interaction with other African-American students, their engagement in the class, and their engagement with the course leadership or the professor and the teaching assistants. The specific protocol for the observations is found within the appendix 1e. Observations occurred of all seven students within the study population.

3.4 Data Analysis

To analyze the data, I employed qualitative data analyses. I coded student experiences from interview discussions and gathered observations, creating themes that related to the students' internal perceptions and coping responses. To generate those codes and themes, I utilized the PVEST framework along with existing research literature to ascertain students' net vulnuerability, stress engagements, and coping mechanisms. To create these codes, I used an iterative coding process where I read the data in its entirety, and used deductive coding based on the PVEST frame. I reflected over these codes in relation to the existing research literature to generate a theme (see Tabel 1). Other points of study included students' exposure to the major and in course seminars with follow-ups asking if the exposure influenced their perception of the major. The interviews provide evidence about their experiences, supporting my analysis of characterizing the department culture and its effects.

Data analysis exemplar of coding scheme.

Table 1

Theme: Perception of Culture	
Code: Representation affords students an opportunity to vicariously feel success and reassurance by the example of their predecessors. [6,7,10]	**Data Exemplar**: Ask specifically about the impact of having a Black instructor [myself] had on her experience within the introductory course. "Yeah. [be]cause it, it, it kind of gives you an idea like that. This is possible for someone like me. Yeah, because I mean, I feel like in many scientific fields in general, there is a lot of Caucasian people there, and it's kind of discouraging when you don't

	see someone like you. There, or someone who has a path like yours being almost done with grad school so that kind of gives me hope like yeah, I can do this."S1
Code: Interactive educational experiences instead of traditional methods give students an opportunity to establish their education in a context realistic and relevant to them. [9]	**Data Exemplar:** Asked what was beneficial from the course to them "I want to know like what corresponds to it like I'm learning chemistry what [and] how does that correspond to chemical engineering, what from chemistry, am I [going to]gonna take or have to know that I have to use as a chemical engineer"-S1 Okay, so that class, I really don't understand that class that much to me. It's like it just gives me a lot of homework and I'm just like, what is this. It doesn't really connect.-S3
Code: Lack of inclusivity within peers and the department can cause maladaptive behavior of self-isolation and the internal dichotomy between their identity and the chemical engineering major.[45,52]	**Data Exemplar:** "I really had no connection once class ended, after class I was just lived as a Black student and being a ChE wasn't relevant to my life again until I'm doing homework back in class"-S1
Code: Prior experiences of students must be considered in engagements to reestablish an inclusive environment. [45,49,52]	**Data Exemplar:** Ask about her lack of seeking out help even when needed " In all my other math and science courses all my questions were not really answered. Professors really did not take time to get what I wasn't understanding so by the time I had questions about this class I had given up trying to discuss frustrations to someone. Just felt like we didn't speak the same language."
Code: Empowered feeling of accomplishment following individual perseverance	**Data Exemplar:** No, I just think it is more of the society point of view of a black man doing this still major, which is not like the norm, so it is like I got to prove to myself that I'm going to graduate with this degree.-S3

Chapter 4: Findings

Chapter four constitutes the findings of this study. I present these findings based on the themes developed: perception of culture, the impact of the culture on student experience, and students' strategies and initiatives employed to succeed.

4.1 Perception of Culture

A major focus of my observations and interviews was the characterization of the overall culture of the Chemical Engineering department within the University of Missouri. The perception of the environment the students were in was almost identical across the board from the students' and my own personal accounts. Within the conceptual framework of PVEST, much of what I discuss will falls in line with the net vulnerability and net stress engagements stages. When asked about the culture, the consensus answer was that there was a strong awareness that the predominant culture of the department is based upon and favors white and male. "This is the PWI so like this deal with people for standard there's like a lot of white people in general, but I'm surprised that there's quite a few blacks at Mizzou in other majors" (Student Three). The participants were far more aware of their identities as it relates to their environment than other students within the department. For example, when asked about how identity effected her experiences Student One stated, "I guess, I don't know, to be honest, I like the field and the school, I guess, but I honestly don't mind being around like white people or Asian people but certainly somedays its noticanle to me that theres not many like me." The students are aware of how few African-American are in the program and it has an effect on how they view their own fit within the program. The three interviewed students had varying motivations of why they entered the major, but none had a direct connection to the field prior to enrollment. Student One described their motivation as a general talent that was recognized by a teacher in high school who made the suggestion to her. This differed from Student Two who reported, “It [chemical engineering] was really just something I looked into cause the how the major was described seemed interesting since I was good enjoyed chemistry.” Lastly, Student Three discussed,that he simply had a passion for the environment and chemical engineering was something he saw that could direct him to work within his passion. None had a direct point of contact like a family member in chemical engineering to provide a better understanding of the field prior to entering the field. They each had indirect and loosely related talents or interests that led them to the field. Examples of which were high school teachers advising them toward engineering following success in their math and science courses. For example, Student One shared, “My guidance counselour just kept suggesting engineering, and when I looked into it chemical stuck out, but I really only went off the description. ” All three participants mentioned that having a Black teaching assistant was beneficial to them. When asked about the impact or having myself as a Black instructor, Student Three stated, “Now I’d be fine either way but I would probably be way more comfortable going to the TA that was also Black at the begininng of the semester.” This response demonstrated the indirect influence having someone who looked like them had on their engagement as it shows an increased relatibility. Alternatively, two of the participants shared that engaging with a Black teaching assistant had a direct influence on them. For example, Student One stated:

> Yeah. [be]cause it, it, it kind of gives you an idea like that. This is possible for someone like me. Yeah, because I mean, I feel like in many scientific fields in general, there is a lot of Caucasian people there, and it's kind of discouraging when you don't see someone like

> you. There, or someone who has a path like yours being almost done with grad school so that kind of gives me hope like yeah, I can do this.

Here, Student One reveals that as the TA, my progression within the major into graduate school served as an example that success in ChE is possible for individuals like themselves. Of the three students interviewed, they all agreed that the department (peer, staff, and faculty) was generally accepting of their identities. They each characterized the department as supportive and friendly toward them. Student One stated, “Overall I would say people at least try to set time aside to be helpful.” They were also each unaware of resources available to them, if any, offered by the ChE department. They knew of NSBE at Mizzou, as the only resource for Black engineers with only one student being personally involved. Student Three shared, “It was nice being involved but there were really people in my classes like everyone else seemed to have.” They enjoyed the organization but wished to have something specific to chemical engineering since the representation of ChEs within NSBE is low. During the interview, I specifically brought up the inclusivity center within the Mizzou College of Engineering. The inclusivity center is a space established in 2017 that is dedicated to presenting a space that actively supports students of all backgrounds. In asking about the inclusivity center, the participants stated that they were all aware of the center but one specifically shared he has not visited it yet because he really doesn’t know what to use it for; “I just never had much of a reason to check it, I don’t really hear about it” (Student Two). Their perception gained from their experiences in the introductory course were positive. The students appreciated both the teaching assistants and course faculty. For example, Student Two explained, “Y’all (myself, the other TA, and the faculty member) have for sure go out of y’all’s way to be helpful and make sure we enjoy the course.”

All three of the students agreed that the introductory course was necessary for them to better understand ChE as a major. Within the course, the students discussed the various activites that were provided, the topics reviwed, and the concepts presented. In the introductory course, students were exposed to mass balance within the H_2O experiment within Appendix 1a, Student One stated following; “I liked corresponding what we do in class to something I can see so I really know what chemical engineers do.” The participants stated that they saw value in the possible career and educational options in chemical engineering that were discussed. Along with the career presentation, the students had the opportunity to virtually meet Mizzou chemical engineering alums to learn about their experiences and how they currently utilize their degree. The alumni interaction was again helpful because all students were able to ask which specific courses in the chemical engineering curriculum prepared them for their careers. For example, Student Three shared, “It was nice that they cared enough to speak with us, and that they said the things we do in our classes will actually be used later in life.” Another contribution the course made was a detailed breakdown of the future courses and concepts discussed in classes necessary for the degree. Regarding this experience, Student One stated, “I’m glad you all laid out what all needed to take so I know more what I got into.”

Each agreed on the positive aspects of pursuit and attainment of a chemical engineering degree. The experiences they valued the most were the ones that allowed insight into the major and its utility. The negative responses were mostly related to the pace of instruction when it came to chemical engineering concepts. One observation I made through class interactions and office hour was that all the students had large discrepancies in their K-12 education, especially as it related to their mathematical methodology from previous algebra and/or calculus courses. Getting the students to think conceptually about fundamental chemical engineering topics was difficult when many were still grasping an abstract understanding of general mathematics and chemistry. An example of this was there was an early assignment involving limiting reagents. Half the course had experience in high school solving limiting reagent problems. The topic had not yet been covered in their general chemistry course and caused a great deal of stress and confusion to students without the previous experience. Student Three had a helpful suggestion of designing the course in unison with their projected courses. They stated, “If we just took what we did in our other classes and repurposed them to chemical engineering would be more helpful than new things we brought up in this class.” This statement helped provide insight into how students perceived the overall culture of the course, including areas that needed improvement.

Overall, in defining the culture of their major and the course, the students collectively shared that is was a positive experience, but could have been more helpful by giving them more examples and experiences to make chemical engineering more relevant to them.

4.2 Impact of Culture

In the established PVEST framework I will discuss the impact of the culture and their perceptions on them as individuals. The net stresses the students faced generated different reactive coping mechanisms, emergent identities, and ultimately stage-specific coping outcomes. I gathered the resulting behaviors from their interview responses and observations. Recurring pressures (net stress) they all faced were an immediate academic success, social dichotomy, and limited representation. These stresses reflected different components of the precieved culture of ChE. Academic success related to them not knowing anyone directly within the field to normalize the struggles they faced. Social dichotomy is found in the example provided by Student One who stated “I really had no connection once class ended, after class I was just lived as a Black student and being a ChE wasn't relevant to my life again until I'm doing homework back in class." This highlights the identity division she felt between her race and major. The limited representation hallmarked ChE as a white space. Each understood that chemical engineering was a difficult major before enrolling and they did not have anyone they knew who was a chemical engineer to discuss some of the difficulties they would face. They each, in their personal interviews, stated that they felt discouraged early during the course due to struggles in adjusting and learning materials. For example, Student Two shared, that in her previous experiences she was only ever given assistance with lukewarm interest and she felt strongly discourage in engaging with faculty for help. Their statement was similar to Student Three who shared that he initially self-isolated because everything came to him as a culture shock and once he found comfort he was able to work better with peers and ask for assistance. All of the students quickly internalized that their experienced challenges in their major stemmed from a lack of ability or effort instead of a perceiving or anticipating a normal adjustment within their college careers. The social dichotomy reflected the adjustments the students made that were mutually exclusive to the different aspects of their lives. They saw themselves as active participants in department culture, however, they saw their Black student experience as very separate from their major. They did not attach the major to their identity as non-Black students did. For example, Student Two shared that the majority of the class quickly formed small subpeer groups that studied and socialized together while she did not experience interaction with her peers beyond studying of class time.

4.3 Strategies and Initiatives to Succeed

Within this section, I further explain students' coping mechaninsms employed within their environment and how those coping mechanisms influenced their experience in introductory course. Each student demonstrated some form of adaptive or maladaptive coping behaviors. For example, some adaptive coping behaviors the students demonstrated were empowerment felt by Student Three. These behaviors were primarily demonstrated in response to stress engagements such as personal accountable for shortcomings and drive for better future outcomes. These behaviors were adaptive in that they contributed to the students' motivation to succeed; what Student Three noted as being his own example or role-model. Examples of maladaptive behaviors includ Student Two's retraction from course involvement and assignments. These behaviors were generated in response to stress engagements such as the lack of understanding given communication differences between her and faculty within other courses, "It was like they did not speak the same language and that faculty did not make an effort to understand my confusion." These behaviors were maladaptive in that they pushed her to avoid circumstances and supports that would support her continued development and success in the program. The students even discussed some of the coping behaviors. Student One, in response to a question designed to ask how the student adjusted to succeed, responded, that "I began to work and bond with the other women of the course." Their bonding was based on gendered-underrepresentation. The participants also provided suggestions as to how the course could have played a larger role in their ChE experience and specific needs the course could not fulfill alone. Such suggestions included, "Maybe making the career outlook a bigger portion of the class" (Student One), "Spending more time in activities just so we can better relate the math and science to something useful" (Student Three), and "Assistance in co-enrolled classes since adding new material just doubled down on things I already stuggled with [without addition help] made this course stress a lot of the time” (Student Two). These suggestions provide insight into additional stress engagements that students experienced (i.e., isolation) and corresponding coping strategies (i.e., personal empowerment). These inferences are based on the students’ desire to see themselves feel included and successful within the field.

4.3.4 Additional Notes

Aside from the stated incidents in which I observed the particiapnts behaivors and engagements, there were other salient moments that contributed to my understanding of 1st-year, Black students’ ChE experience. The best observation I had of all the black students of the course was through help session attendance and even seating arrangement. Black students began the semester randomly distributed throughout the room. Later in the semester, many began to position themselves in spaces towards the back of the class, demonstrating behaviors that suggested the course was not perceived as relevant and that it failed to engage them. Some began to sit and work in small clusters. One Black female student intermingled with the other woman in the course the whole semester as well as the instructors.

Discussion

Production of capable engineers is a principle driving force for economic development, innovations, and the environmental impact of various societies. Diversity in science, technology, engineering, and mathematics (STEM) fields has contributed to further innovation by adding variety in mindset and perspectives. Throughout the United States, only approximately one-half of students that initially indicate interest in an engineering degree follow through to the actual attainment of that degree. These statistics are highly dependent upon race, ethnicity, and gender, with African-American students receiving degrees at a rate of 38.3% compared to 59.7% for White students. African-Americans comprise 5.1% of the initial enrollment of engineering majors. Collectively, these figures reflect the very visible reality of the severe underrepresentation of African-Americans within the engineering profession. In considering these facts in relation to students' undergraduate experiences, research suggests that Black student attrition in engineering throughout their undergraduate studies prompts their underrepresentation within the field. In looking to examine what contributes to Black students' persistence or attrition in engineering, specifically chemcical engineering, this study examined the experiences of first-year, Black students enrolled in an introductory checmical engineering course. The findings from this study focused on how their identity as Black students shaped and informed the daily experiences and responses to those experiences. Through the PVEST frame, I explore and potentially explain the relationship between their racial identity (net vulnuerability) their experiences in their major (stress engagements) and their responses generated to persist (reactive coping mechanisms).

5.1.1 Net vulnerability is described as an individuals experience history and coping outcomes that predisposes them to certain behaviors and reponses. In this study, the students' Black racial identity was the focus of their net vulnerability as it shaped and informed how they both saw themselves within their major as well as what components of their major and the introductory course stood out to them. As Black students, they all reported they came from predominately Black K-12 institution and were weary of the cultural transition to a large PWI like Mizzou. Two made statements relating to the 2015 racially motivated protest on Mizzou's campus. They spoke on how the events and university response to them made them more cautious about how they may be received as Black students on Mizzou's campus. This perception followed by little representation within the department developed their anxiety of success within the major of chemical engineering. Entering with anxiousness for belonging and success negatively effected their self perception when met with opposition or personal shortcomings. The net vulnerability also instilled in some a sense of responsibility to be the example they wanted to see within the major. These students showed great perserverance and maturity in comparsion to their peers. These student however were more hesitate to seek assistance from peers and faculty due to an inclination to resolve problems or confusion themselves.

5.1.2 Stress engagements, per PVEST, are described as actual experiences that challenge or support the indivuals well being. In this study, the main stress engagements noted were academic, social, and interpersonal. Academic stress involved the students' interaction with the course concepts presented. Given their identities and previous experiences, the students felt that some of these concepts were benefical and supportive (i.e., supplemental help sessions) while some of these concepts were challenging and possibly unnecessary (i.e., culturally exclusive nature of peers). The students' recommendations for course changes provided insight into how they associated different componets of the course with their own identity, or how vulnerable they were in this space given their identity and experiences. Social stress involved the dichotomy students faced between racial identity and the ChE field in which they studied. My participants disassociated their positive racial identity-informed social experiences with their experiences as a ChE student. This indicated that the students did not perceive their ChE spaces to be socially-affirming and welcoming as it pertained to their understanding of their Blackness. Instead, their Blackness prompted a challenging, and socially-isolating ChE experience. Interpersonal stress involved the lack of representation within their major, supporting their social dichotomous perception. Interpersonal stress led to students feeling as if their Black identity and subsequent experience was separate from their chemical engineering major and experience. In noting the challenges that all incoming chemical engineering students face, the department decided to create an introductory chemical engineering course. This course was designed to provide nurture an interest in the field of chemical engineering while also depicting the work with the degree plan and career outlook. As described throughout the data, the participants found this course to be a supportive mechanism for their overall academic engagement. They specifically appreciated the connection they were able to make with their own identity and the major; a supportive mechanism facilitated by me being a Black male teaching assistant. Whereas other components of the learning environment facilitated support (i.e., alumni visits, career explorations, etc.) the interpseronal relationship they were able to develop with me, seemed to be salient and important for their success and engagement. These success, as previously noted, were limited to the students' academic perceptions and experiences and not their social experiences. While some people may argue that the dempartmental culture should solely focus on academic success and preparation, as indicated by some of the students' behaviors, the lack of social connection to the department and major prompted isolating experiences. ChE departments must attend to the social nature of learning aside from the academic support in order to fully support Black students' retention and inclusive experience.

5.1.3. Reactive coping mechanisms are the actions to resolve the situation following the challenge or support presented to the student. The support of having a Black teaching assistant caused all three students interviewed to be more open with their struggles and improve help seeking behaviors to resolve their confusions. The other supports in the form of activities and career exploration gave students tools to better relate to their course work and the ability to better align their course experiences with their professional goals and interest. Their challenge of unrepresentation among their peers and faculty led two of the three (Student Two and Three) to perform coping mechanisms that further separated themselves from others. Student Two avoiding potentially frustrationing interactions due to a repeated history of misunderstanding coupled with a lack of patience is one example. Student Three approached the same issue with a sense of reponsiblity and self determination to succeed, which also made him hesitate in looking for outside assistance. In noting these coping mechaninsms, it is important to understand that coping responses, per PVEST, are generated based on the students' perceptions of challenges and available support within their stress engagements. This suggests that we recognize these behaviors, the students' removal from others, as contextual failures to provide an adequate, supportive environment that instills appropriate tools, strategies, and support mechanisms for students. These coping strategies also implicate the perceived challenges that prompted these behaviors, suggesting that ChE departments and context must be mindful of how they push students to feel as if they must work independently to be successful.

CONCLUSION and IMPLICATIONS

As stated by Clemson President James P. Clements, "In order for the U.S. industry to remain a global innovation leader, universities must graduate more engineers, including more minority and women engineers." This study examined the experiences of three Black, 1st-year Chemical Engineering students at Mizzou. Taking into an account their identity (net vulnerability), experiences (stress engagements), and responses (reactive coping), this study reveals the culture of the Mizzou ChE department and major and its negative and positive implications on Black students. In noting these students' experiences, more attention must be put towards redressing structures within ChE that perpetatue academic, social, and interpersonal challenges for Black students. In attending to 1st-year student experiences, this study provides the opportunity for identifying targeted areas for future interventions that will foster an inclusive environment for Black students.

According to the article, “Taking Another Look at Educating African American Engineers: The Importance of Undergraduate Retention” pubished in the *Journal of Engineering Education*, attacking 1st-year attrition is a possible goal that can work towards increasing the diversity within engineering. This study suggested that schools set small goals of meeting a 50% retention rate of their Black students. In considering this goal within the context of this study, the current Chem E 1000 course has 7 African-American students out of 58 total students. If current trends persist, 2 of the 7 Black students will complete their degree of a total class of 27 (other students were taken at 50% retention rate) and compose approximately 7% of that graduating class. With an increase to 50%, retention for African-Americans that figure becomes four graduates of 29 the total class and now composes up to 13.9% of the class. With the simple retention of two individuals, the graduating class representation at The University of Missouri now more closely reflects the demographics of Missouri as a state and the nation as a whole. This feasible goal would then benefit classes to follow when there are more cultural brokers to not only mentor underclassmen but also influence the department culture to more accustomed and welcoming to black students. A simplified expansion of it is that if each of the 4 students reaches senior status in their fourth year and similarly enrolled classes follow (8 within the first-year class with 25% attrition after their first year and another 25% attrition of the original number following their third year, simplified for example sake). That gives a picture of 4 seniors, 6 juniors, 6 sophomores, and 8. That is a total of 10 upperclassmen mentoring 14 black underclassmen, which has the potential to produce a capable mentorship structure. This is an example of the power of fully developing the already present resources. This still, however, does not address the representation gap of the faculty and leadership at the university. And while this simple goal prompts diversity and has the potential to support inclusion, it does not nor should not be the end goal of the Mizzou ChE department. Moving beyond 50% retention to 100% retention, with an increase in the number of Black students enrolled in the major is a more adequate, appropriate goal. This idea, combined with structures to redress cultural inequities can better foster student success and inclusion.

The continued identification an individual has with their own culture is necessary and a basic need of many as it relates to one's self-image which is a factor in educational success. Individuals that can act as social bridge-builders can be incredibly important in an educational setting. Defined as cultural brokers in the *Journal of Negro Education*, these individuals act as agents to bridge divides from mainstream culture to a specific subculture, in this case, African-American culture. Culture brokers act as not only links of communication and teachers of adaptive strategies for particular students, but they also act as role models to aspire their community to participate in mainstream activities like chemical engineering education. HBCUs again have a vast advantage in this area by having representation in leadership from African-Americans in various backgrounds reflecting the experiences of their students. The comfort a student would have to a potential broker can be predicted by how closely that broker relates to that student. Any two students identifying as Black may have some overlapping experiences, but also may have vastly different exposures and expressions. For example, being a Black student with American family history compared to black students with African or Caribbean immigrant family history have some cultural overlap but varies vastly in some educational hindrances and self-image.

These differences manifest themselves in different retention trends and needs that HBCUs are more geared to address than PWIs, due to PWIs have a limited diversity within black representation. Recognizing the challenges that PWIs face with limited diversity, there are initiatives that these institutions can take to provide a stronger, more inclusive culture for Black students. For example, within the context of this study, both myself as a Black male graduate TA and the NSBE organization served as one form of a "cultural broker" for the participants. In this study, both myself and this organization provided appropriate linkages between the students' lived experiences and their professional goals within ChE. And while we were able to provide some support to the Black students, there is more support that is needed.

Specifically, Mizzou can invest more support in its initiatives like NSBE and the diversity and inclusivity center currently active in the College of Engineering. The issue that can be immediately addressed is the effort to connect incoming chemical engineering freshmen to the resources already available, as well as investing more resources in these spaces so that they can better serve all of the students. Before new initiatives and program formation should be attempted there should be a review into the optimization of current support systems. Emphasis needs to be placed on this initial exposure to chemical engineering to African-American students. The limited perception many enter the department makes that initial access point critical to their sense of belonging. Mizzou chemical engineering has fallen short of creating a sense of inclusivity by having limited engagement opportunities, no representation, and minimal cultural awareness as it relates to educating Black students. A strong predictive index in the first-year retention is mainly rooted in preparedness, for future retention, it is best to lay the groundwork for graduation to employment by exposing of K-12 Black students to engineering and building the pipeline to a point prospective students see the value in the attempt. Further work needs to be lead in tracing enrollment of African-American students and their retention. As well, more resources and support need to be invested in attracking Black graduate students and faculty to the department to serve in mentoring and leadership capacities.

To properly improve retention at Mizzou a better understanding of our existing community is necessary and following that internal audit, the institution must find a unique solution for the population it serves. Whether it be organizational involvement (PEER model), improved representation practices, career outlook advancement, and/or cultural development. This audit cannot not be replete of incremental steps made to enhance Black student experience. There must be a combination of additional research and investments made, simultaneously, to ensure that long-term structural changes are addressed while short-term gains of supporting students are maintained.

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Appendix

1: Activities

1a: Activity 1: H20 Activity for CH_ENG 1000/1000H

Lead Instructor(s) for this Activity: Jeff Cathey and Lucas Haley

Objective of this Activity

The intention of this experiment is to assist students to gain a fundamental understanding of gathering field data and in particular flow characteristics. Aspects of this activity that are inherent to developing an appreciation of process engineering include the measurement of flow rates, pressures, and their relationship with pressure drops and material balance.

Supplied Materials for Completing this Activity

- Stopwatch
- Graduated bucket
- Jet nozzle
- Spray nozzle
- Pressure gauge
- Flowmeter

Theoretical Background

The theory of the activity is a simple observation of the conservation of mass and force within a system. Using a manifold with various junctions and restrictions, a water inlet starting from an external tap at Lafferre Hall (aka, the hydrant), assumed to possess constant flow rate, will be branched into a series of with terminals at operating at varying levels of flow.

Analogous to electrical current flow which you studied in physics, the total water flow rate within the water system, F_{total} , must equate to the summation of all individual terminal flow rates, F_i .

$F_{total} = \sum Fi\ N\ 0$

Procedure

Students are asked to self-assemble into teams composed of three individuals each. They should then seek out the assistance of a graduate teaching assistant, who will assign each team to an outlet. Each team will then make the following measurements:

- Pressure

Pressure will gather as a whole for each section of the testing apparatus. Be sure all valves are open and pressure gauges are attached at all stream outlets with exception of one of the 2 most downstream outlets. One of these needs to be left open.

Be sure outlets are as physically-leveled as possible. A GTA will open the valve on the hydrant allowing water to begin to flow throughout the system. Please allow the system a few minutes to reach a steady-state flow equilibration before gathering data from your measurements.

Pressure gauges are attached at each outlet port to measure outlet pressures. Be sure to document pressure drops along with the network.

- Flow Rate

After your team is assigned to an outlet with a graduated bucket, you will need to do the following:

1. Examine that their valves are all open and testing apparatus is level.

2. Assign timer and bucket holder responsibilities to individual team members.

3. Begin to fill bucket without a nozzle while another group member measures the time that it takes to fill. Record the fill time for each graduated mark.

4. Repeat steps 1-3 with a jet nozzle and spray nozzle

- Material Balance/Data Analysis

From the data you collected, you should be able to use Excel, or a similar spreadsheet program, to plot your data, calculate flow rates, and use your data to calculate expected flow rates from each outlet and the overall initial flow rate.

Reporting

Each team needs to submit a laboratory report (2-4 pages) as their homework assignment for this week. The report must be formatted as follows:

1. Title of Activity

2. Name of each team member

3. Table of raw data for each series of measurements:

a. The column of times

b. Column of volume

c. Column of changes in time

d. Column of changes in volume

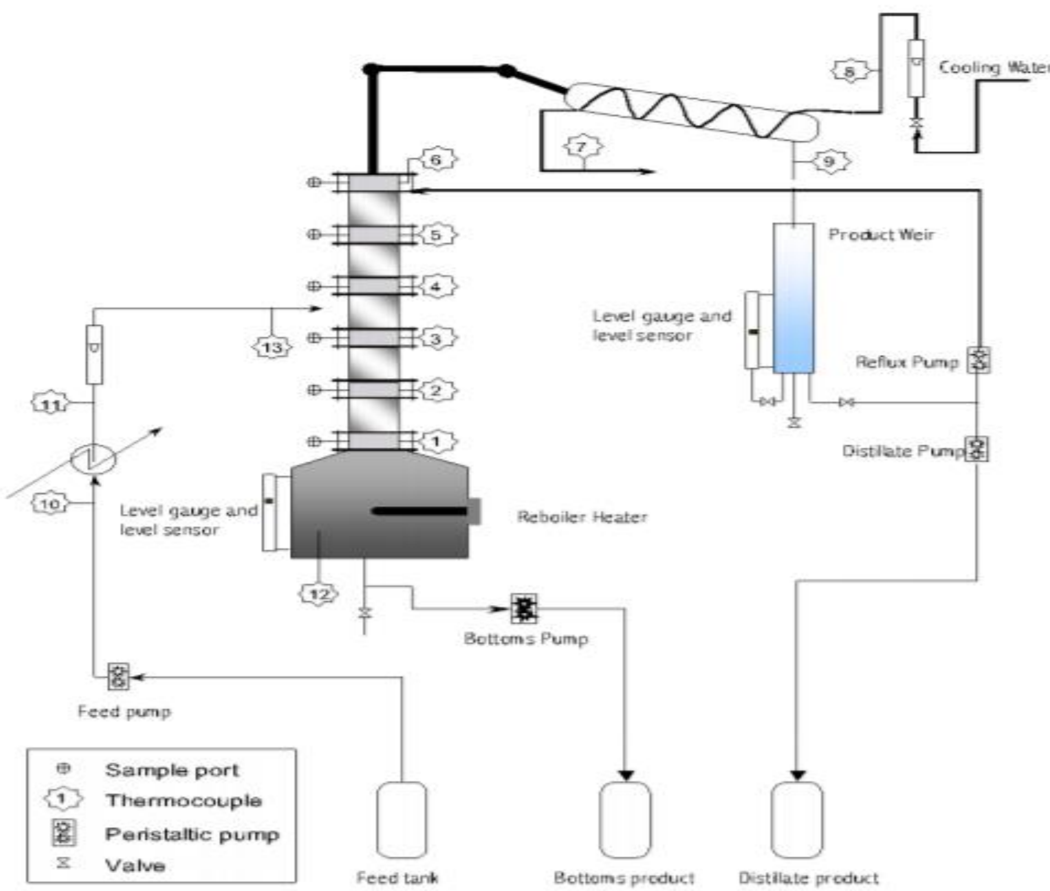
4. A single plot of volume vs. time for each measurement containing a legend and easy to discern points/curves; a fit of the data (linear, log-linear, Lorentzian, etc.) and pertinent values from that fit.

5. A discussion of the data and accompanying data analysis interpreting the measurement, an analysis of these measurements in terms of materials balances, and whether their measurements and accompanying extrapolation matches what they should have expected and if there is a discrepancy → are there sources that are responsible.

6. Please do not insert opinions or comments. We will be conducting a follow-up survey in about 1 week to determine if this activity met the outcomes we were targeting, and conducting a "lessons learned" in order to improve or enrich the experience.

1b: Activity 2: Distillation Activity for CH_ENG 1000/1000H Objective

The objective of this activity is to understand how a distillation column functions to separate compounds through the model binary distillation of methanol and water. Materials • Distillation column • Methanol • Water • Vials • pipette • Refractometer Background Distillation is a unit operation and a process of physically separating a mixture into two or more products that have different boiling points (i.e., volatility), by preferentially boiling the more volatile components out of the mixture. When a liquid mixture of two volatile components is heated, the vapor that comes off will have a higher concentration of the more volatile compound than the liquid from which it evolved. Conversely, if vapor is cooled, the less volatile material tends to condense in a greater proportion than the more volatile material. Procedure 1. Inspect the distillation column with GTA assistance 2. Acquire samples from the reboiler, two-column trays, distillate, and feedstock 3. Measure the refractive index of each sample in the refractometer Reporting 1. Determine the composition of each sample using the supplied calibration curve 2. Describe the purpose of the following distillation components. Reboiler b. Column trays c. Condenser 3. What properties of methanol and water allow the two to be separated through distillation?



calibration

% meth	Rf index
0	1.3316
10	1.3341
20	1.3359
30	1.3381
40	1.3398
50	1.3408
60	1.3408
70	1.3403
80	1.3386
90	1.3348
100	1.3277

design run 1

total dist

tray	rf index	rf index
1	1.3408	1.3408
2	1.3389	1.3375
3	1.337	1.3356
4	1.3346	1.3338
5	1.3335	1.3327
6	1.3329	1.3318
distilate	1.3329	1.332

Feed 1.3377
~25% methanol

partial

tray	rf index	rf index
1	1.3402	1.3388
2	1.3399	1.3395
3	1.3404	1.3405
4	1.3372	1.3372
5	1.3351	1.3355
6	1.3334	1.333
distillate	1.3333	1.3331
bottoms	1.3335	1.337

design run 2

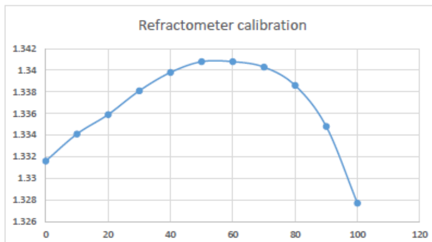
total dist

tray	rf index	rf index
1	1.3397	1.3387
2	1.3378	1.3352
3	1.3355	1.333
4	1.3333	1.3324
5	1.3326	1.3309
6	1.3321	1.3302
distilate	1.3321	1.3302

Feed 1.3398
~40% methanol

partial

tray	rf index	rf index
1	1.3404	1.3404
2	1.3409	1.3404
3	1.3403	1.3398
4	1.337	1.3358
5	1.3343	1.3339
6	1.3333	1.3321
distillate	1.3311	1.3309
bottoms	1.3381	1.3381



design run 1

Time H/M/S	REFLUX TYPE	REFLUX RATIO	Cool IN º C	Cool OUT º C	REBOILER º C	TRAY 1 º C	TRAY 2 º C	TRAY 3 º C	TRAY 4 º C	TRAY 5 º C	TRAY 6 º C	DistTemp º C	FEED T º C	Reflux mL/Min	Product mL/Min	Bottoms mL/Min	FEED mL/Min
6:27:58	TOTAL	2.8	26.14	28.69	85.27	74.35	70.61	68.57	67.62	64.88	66.57	43.12	33.31	77.72	0	0	0
6:30:53	TOTAL	2.8	26.68	29.16	85.31	74.1	70.51	68.31	67.23	64.42	65.43	43.29	32.98	81.2	0	0	0
6:44:15	REFLUX	2.8	28.58	30.73	85.61	82.04	80.2	74.37	69.81	65.19	66.84	43.6	64.8	47.35	16.91	83.09	100
6:47:39	REFLUX	2.8	29.06	31.26	85.74	81.8	80.29	73.77	69.63	65.78	66.87	44.27	64.4	50.46	18.02	81.98	100

1c: Activity 3: ChemE Car: Activity for ChemE 1000/ChemE 1000H

Project Objective: Students will design a car that is powered solely by a chemical reaction and can travel 25 feet.

Example car

Car Design: K'NEX™ or LEGO™ kits and medium size (approx. 750ml) plastic water bottles.

Chemical Reaction:

$$Vinegar(liquid) + BakingSoda(solid) \Rightarrow Water(liquid) + CarbonDioxide(gas) + SodiumAcetate(aq.)$$
$$[AceticAcid + Water] + SodiumBicarbonate \Rightarrow Water + CarbonDioxide + SodiumAcetate$$
$$[CH_3COOH(aq.) + H_2O(l)] + NaHCO_3(s) \Rightarrow H_2O(l) + CO_2(g) + NaCH_3COO(aq.)$$

The above equations are all representations of the same reaction. It is important to note that for a complete reaction the molar ratio of acetic acid to sodium bicarbonate must be kept constant.

Ingredients: Kitchen Chemistry at its Best!

Explanation:

The third equation above shows the balanced form of the reaction. As noted, the reaction requires one mole of acetic acid and one mole of baking soda to produce one mole of carbon dioxide gas. A mole is a unit like a dozen, a dozen is 12 things and a mole is 602,200,000,000,000,000,000,000 things. For comparison a mole of donut holes would cover the earth and be 5 miles deep. However, a mole of molecules can be a reasonable amount. One mole of water is only 18 ml. Moles are used in chemistry because it allows comparisons to be made regardless of phase or measurement units.

Our goal in this experiment will be to always use excess vinegar to help make sure all the baking soda is dissolved and reacted. Once we understand the chemistry, we will attempt different chemical ratios to produce enough gas to drive our cars approximately 25 feet.

Procedure:

While the exact details of this experiment are quite open, a general procedure is outlined below. Prior to building the cars, it is a good idea to develop an understanding for how much gas will be produced. Thus the procedure is broken into three sections: gas production, car construction, and car operation (distance traveled).

Gas Production (plastic bottle chemistry)

In a plastic bottle (any approx. 750 ml water bottle with a small mouth will work for this) add ~100 ml 5% acetic acid Vinegar. (Vinegar is sold in 4% and 5%.

Wrap ~6 gm Baking Soda in a single-ply Kleenex and add to the vinegar.

Immediately cover the bottle opening with a balloon and hold it on to prevent leaks. (It is good to practice this with out the reactants once or twice.)

Gently shake to bottle to encourage mixing. The reaction produces gas and will blow up the balloon. Measure the balloon diameter with a piece of string or a measuring tape.

Repeat a few times with a few different reactant ratios. (The original ratios were chosen as they are a 1-1 molar ratio.)

Car Construction

Discuss the important features of the car design (wheels that spin, a way to secure the reaction chamber (plastic bottles), the direction of the jet and the way the car then moves).

NOTE: Cars can be constructed out of almost anything that allows you to put wheels and axles on a platform. We use either K'NEX™ or LEGO™ kits for simplicity, but wood or a plastic model kit would also work.

Allow students to build car.

After a test run, checking for wheels that work, bottle secured, and structural stability, reconstruct if necessary.

NOTE: The concept we are trying to teach here is engineering problem solving - design and re-design. We learned that the "re-design concept" is not well received by 1st graders. However, the "take-apart-and-build-all-over-again" concept does seem to work...with some coaching.

Make sure the plastic bottle used as a reaction vessel can hold a good seal and still be easily opened.

NOTE:700 ml GATORADE™ bottle with the simple "one turn to open" lid. Any flavor POWERADE™ bottle works fine .

SOURCE: https://engineering.oregonstate.edu/momentum/k12/march04/index.html

1d: One-on-One Interview Question Guide

Script

Hello. I am a member of the Chemical Engineering Mizzou research team looking into freshmen immersion and. Thank you for deciding to participate in our research study. Your contributions are important, as the information you share will help shape STEM undergraduate education in the future. Today I wanted to talk with you about your lived experiences and identity. As you may know, this research project strives to understand undergraduate students' conception of their identity and experience in their STEM programs. This interview is one of the few pieces of data that we are gathering to develop this understanding.

Your responses will remain confidential! Nothing that you share will affect your enrollment or grades at the University of Missouri. Your identity will be protected in any research reported from this study! In reporting any themes or findings, a pseudonym will be used in place of your name, or any names that you provide (be it the names of a person, location, or thing) that can be traced back to you.

We will audio record this interview. If there is any moment in which you wish to turn off the recording, you have the right to make that request. Additionally, if there is any question that you do not wish to answer, you have the right to refuse to answer. Should you change your mind about participating during the interview process, you also have the right to withdraw from the study.

This is a completely informal interview; we want you to be as relaxed, open, and honest as possible. This interview should not take any longer than 1 hour. If you agree to participate and are comfortable with these terms, please give verbal consent, and we will begin.

1 Questions:

1. Please share your name, classification, and major (or program of study).
2. How would you explain what your major is to someone who is not in your major or never heard of it?
    a. What would you say you study in your major?
    b. What would you say you do in your major?
    c. What would you say is the purpose (overall/ in life) of your major?
    d. What outcomes (products, inventions, opportunities) come from your major?
3. How would you define the general culture of your major?
    a. What are the general, or "understood" rules and expectations about studying your major or being someone with that degree?

b. What type of people are generally considered to be the "type of person" who studies your major or has that degree? (Race, Gender, Characteristics, Qualities)
c. What are common activities, practices, or funds of knowledge associated with your major? (e.g. scientific method)

4. How would you define the general culture of your STEM department? (e.g., friendly, cold, black, white, male, female, supportive, non-supportive)
    a. What are the professors like?
    b. What is the staff like?
    c. What are the students like?
5. What departmental opportunities and resources are available to support students like you?
    a. Do you access them? Why or why not?
    b. How are they supposed to support students?
6. Describe for me what your STEM classes are like.
    a. How are the classed structured? (lecture, small group, discussion, active)
    b. What is the size of the class?
    c. What is the racial and gender make-up of the classes?
    d. How many people in your class share your identities?
    e. What do you normally do in class?

Wrap Up:

7. Is there anything additional you would like to share your thoughts about your major, your department culture, or classes at Mizzou?

2 Questions:

1. Describe your current feelings about how you feel your STEM major values and appreciates your identity.
    a. In what ways do they communicate or show they value and appreciate your identity? If they do not, then why do you feel this way?
2. In what ways, if any, does your department or major celebrates or embraces your identity as (race and gender) or other people who share your identity?
    a. How do they go about doing this?
    b. Who typically leads this? (Person, title or position in the department)
3. In what ways, if any, does your department or major challenge or go against your identity as (race and gender) or other people who share your identity?
    a. How do they go about doing this?
    b. Who typically leads this? (Person, title or position in the department)
4. In what ways, if any, does your department or major create space, time, or opportunity to support you as (race and gender) or other people who share your identity?
    a. How do they go about doing this?
    b. Who typically leads this? (Person, title or position in the department)

5. In what ways, if any, do you feel like your department or major does NOT create space, time, or opportunity to support you as (race and gender) or other people who share your identity?
    a. Clarification: Do you feel as if your department ignores you or people like you? Do you feel as if your department intentionally discriminates against you or people like you? Do you feel as if your department better supports or celebrates people who embrace a different identity other than you?

Wrap Up:

6. Is there anything additional that you would like to touch on or share regarding your thoughts and feelings about your major and department as it relates to your identity and experience?

1d: One-on-One Interview 2

Questions:

1. Why did you decide to come to Mizzou?
    a. How did you hear about Mizzou?
    b. What influenced your decision to apply? To attend?
    c. Who, if anyone, helped in your decision-making process? What did they say? How did they help?
2. Why did you decide to pursue your major? What factors influenced your decision? How and why?
3. Tell me about some great experiences, if any, you have had as a student on your campus.
    a. What are they and what made them great?
    b. In what ways have these experiences shaped your view of Mizzou? Why?
4. Tell me about some challenges or negative experiences, if any, you have had or are dealing with as a student on your campus.
    a. What are they and what made them challenging or negative?
    b. In what ways have these experiences shaped your view of Mizzou? Why?
5. Tell me about some great experiences, if any, you have had as a student-specific to your STEM major.
    a. What are they and what made them great?
    b. In what ways have these experiences shaped your view of your major overall? Why?
6. Tell me about some challenges or negative experiences, if any, you have had or are dealing with your major.
    a. What are they and what made them challenging or negative?
    b. In what ways have these experiences shaped your view of your major? Why?
    c. How did you (have you) addressed them? What resources did you use?
7. Tell me about a time, if ever, where you felt really supported by the people in your major.
    a. What was going on during this time?
    b. When did it occur?
    c. What did they do to make you feel really supported?
    d. Why did you pick this story?
8. Tell me about a time, if ever, where you felt unsupported by the people in your major.
    a. What was going on during this time?
    b. When did it occur?
    c. What did they do to make you feel really unsupported?
    d. Why did you pick this story?
9. Tell me about a time, if ever, where you felt isolated or alienated in your STEM major.
    a. What occurred during time?
    b. When did it occur?
    c. Why did you feel isolated or alienated?
    d. How did you address the situation?

    e. How did you address your feelings?

10. Tell me about a time, if ever, where you experienced some form of discrimination in your STEM major.
    a. What occurred during that time?
    b. How were or why do you feel you were discriminated against?
    c. How did you feel when it happened? Why?
    d. How did you address the situation?
    e. How did you address your feelings?
11. What strategies do you use to navigate your STEM major?
    a. Why did you pick those strategies?
    b. How do you apply those strategies?
    c. How effective have they been in helping you navigate your STEM major?
12. What would it take for you to enhance your experience in your STEM major?
    a. Clarification: What changes would need to be made to your current experience (resources, events, people, opportunities, etc.) to make it better?
13. If you had the chance to speak to freshman-year yourself, what advice would you give to yourself in general, and what advice would you give yourself regarding navigating your major here at Mizzou?
14. Besides class, what STEM-related activities do you currently participate in or have participated in since being at Mizzou?
    a. What do you do in those activities?
    b. How did you get involved in those activities?
    c. What do you get out of participating in those activities?
        i. Clarification: Does participating in those activities influence your identity? Do they provide an outlet for you to explore your identity? Do they provide you with more knowledge and exposure?

<u>Wrap Up:</u>

15. Is there anything additional you would like to share regarding what we discussed today?

Thank you for completing this interview. The research team appreciates your willingness to assist us! Stay tuned for communication from someone from the team regarding additional touchpoints.

1e: Observation Protocol:

Monitoring student behavior and demeanor as it relates to the activity they are engaged in, the role the assume in the activity, and their interaction with others during the activity

Institution:	Program:		Date:
Student (s):	Location:		
Time	Activity: Behavior displayed as it results to the activity student is engaged with	Role: Role and responsibilities student assumes	Relationships: Type of interaction with others during activity