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**Stemming stereotype threat: recruitment, retention, and degree attainment in STEM fields for undergraduates from underrepresented backgrounds**

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Dr. Najmah Thomas

Najmah Thomas is an Assistant Professor in the Department of Social Sciences at the University of South Carolina Beaufort (USCB). She is a full-time faculty member for the Human Services Program, which encompasses both the residential/on-campus and the Palmetto College Online degree completion programs. She is also the faculty member for African American Studies at USCB. Her research agenda includes social and economic equity with a focus on program evaluation practices, youth leadership development programs, and public policies impacting underrepresented populations, such as children in foster care and members of the Gullah/Geechee Community. Dr. Thomas earned a B.A. in Public Policy at the College of William and Mary, Williamsburg, VA, a Masters of Adult Education and Distance Learning from the University of Phoenix, and a Ph.D. in Public Policy and Administration with a concentration in urban policy, at Virginia Commonwealth University, Richmond, VA. Prior to her role with USCB, Dr. Thomas served as the Virginia Community College System’s director for statewide Workforce Investment Act programs. She also served as Director of Capacity Building for the Cameron Foundation, and Deputy Director at the Crater Regional Workforce Investment Board in Petersburg, Virginia. Over the course of her career, Dr. Thomas’ work has generated grants and contracts totaling more than $1.5 million. She was named a Southeastern Council of Foundations Hull Fellow, keynote speaker at the Virginia Career Coach Academy and Commencement Address speaker at Fortis College, Richmond, VA. In February of 2013, she received the Living Legacy Award from the Association for the Study of African American Life and History. She currently serves on the Penn Center, Inc. Board of Trustees, and is also a 2017 Fellow with the Institute for African American Research.

Dr. Ronald Erdei:

Dr. Ronald Erdei (pronounced air-day) is an Assistant Professor of Computational Science at the University of South Carolina Beaufort. He completed his PhD in Computer and Information Technology at Purdue University in the summer of 2016, where he had been working and teaching for some years. As of Fall 2017, Dr. Erdei has been the instructor of record (under varying titles) for 14 computer programming or information technology courses. He has helped guide over 750 graduate and undergraduate students to develop not merely technical skills, but more importantly computational thinking abilities, critical thinking abilities, and problem decomposition skills widely considered fundamental to professional success in the modern 21st century workplace.

Dr. Erdei greatly enjoys teaching, and finds the processes involved in learning to be fascinating. His discovery efforts focus on these learning processes with much of his research lying in the learning sciences. Specific topics of interest include: instructional scaffolding in computing disciplines, cooperative learning in college students, pedagogical practices aimed at reducing barriers to the learning process, and optimization of educational content delivery for targeted populations.

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ABSTRACT

This study advances understanding about inclusion, equity and diversity in efforts to broaden participation, transform institutional leadership, and promote student-centered success strategies in academia. The researchers employed qualitative and quantitative systematic review (QSR) to investigate key factors associated with recruitment, retention, and related career attainment in STEM fields for undergraduate students from underrepresented backgrounds. The study is grounded in a review of the literature on stereotype threat in academic settings. Stereotype threat refers to being at risk of confirming, as a self-characteristic, negative stereotypes about one’s social group (Steele and Aronson, 1995). Mechanisms involved in stereotype threat include reduced working memory capacity, changes in physiological processes, lowered performance expectations, negative cognitions, and anxiety. Research suggests stereotype threat can be disruptive enough to impair intellectual performance for students, particularly in undergraduate STEM programs. Although research on the link between stereotype threat and STEM program outcomes is relatively new, initiatives have been implemented in a variety of post-secondary education settings with the goal of enhancing outcomes for individuals from underrepresented backgrounds, using culturally-relevant cognitive and non-cognitive practices. In this study, researchers employ QSR to analyze findings across 25 studies related to promising practices for reducing the impact of stereotype threat in STEM fields for undergraduate students from underrepresented backgrounds. This paper then presents a framework, derived from the findings of the QSR analysis, to describe a proposed theory of change for reducing stereotype threat in academic settings.

KEYWORDS

diversity, inclusion, qualitative systematic review, STEM education, stereotype threat, framework, undergraduate, underrepresented.
Background

Occupations in the science, technology, engineering and math (STEM) fields have increased in overall importance from a variety of perspectives during the past few decades. In terms of individual employment opportunities and overall quality of life, STEM occupations have higher than average job growth projections and higher than average wage rates [1]. STEM occupations are also closely linked to high prestige and economic prosperity from a national standpoint [2]. In terms of practical application, STEM fields are responsible for identification of solutions to myriad challenges in multiple business sectors, government, entertainment, and everyday life.

It is widely acknowledged that the United States must increase its production of individuals skilled in various STEM fields in order to maintain and enhance global competitiveness, and given the deep and wide impact of STEM occupations, it is essential that the field be diverse and representative. General estimates suggest that by 2050, no one race or ethnicity will be a majority of the US population [3]; diversity and representation in the STEM workforce are good principles to pursue on face value, but this issue goes beyond merely doing the right thing. A diverse and representative STEM workforce is essential for ensuring a range of perspectives during solution development [4], is critical for mainstreaming previously non-mainstream topics, and is vital for maximizing innovation [5]. Attracting more individuals from underrepresented backgrounds to the STEM field is essential in many respects, particularly because their knowledge and lived experiences represent an otherwise untapped source.

Despite the clear benefit of a diverse and representative STEM workforce, certain populations, including women, African Americans, Native Americans, and people from Latina/o, ethnic backgrounds have been and continue to be underrepresented in the professional field. This is due in large part to underrepresentation of these populations as STEM degree recipients [6], [7]. It is evident that undergraduate STEM programs can play a significant role in terms of solutions to the STEM pipeline problem. This study uses qualitative and quantitative systematic review to investigate the following research question: What are the key factors associated with recruitment, retention, and related career attainment in STEM fields for undergraduate students from underrepresented backgrounds? A follow-up question is also considered: What specific actions should colleges and universities undertake in order to promote success in STEM programs for more students from underrepresented backgrounds?

Existing research has focused to a large extent on the seemingly intractable gaps in educational outcomes and career attainment for underrepresented individuals in STEM fields. The present study contributes to and expands this research in a practical and generalizable way. By specifically connecting gaps in educational outcomes to the issue of stereotype threat, and by offering an evidenced-based framework to create campus environments which reduce or eliminate stereotype threat in STEM programs, this study advances understanding about inclusion, equity and diversity in efforts to broaden participation, transform institutional leadership, and promote student-centered success strategies in academia.

Literature Review

Underrepresented Groups in STEM
Women, African Americans, Native Americans, and people from Latina/o, ethnic backgrounds continue to be underrepresented across STEM fields. For example, despite some signs of progress, African Americans and individuals of Hispanic backgrounds continue to be underrepresented among credential recipients in STEM fields and in STEM careers [6]. Similarly, women in general and African American women in particular represent less than 29% of all STEM workers [8]. This seemingly intransient issue of underrepresentation in STEM fields is due in part to underrepresentation among STEM program graduates [6], [7]. Although the odds of declaring a STEM major are equal or in some instances greater for these groups, their STEM program retention, degree attainment, and career attainment are still much lower [9]. Researchers suggest a portion of the educational achievement gap can be attributed to socioeconomic status, concentrated poverty levels and continued segregation, particularly in southern schools, but a large portion of the gap remains unexplained [6]. Despite the importance of personality, k-12 academic preparation, and intellectual ability, research must aid in shifting the discourse from one focused on student deficits, to one focused on the role of higher education environments in shaping educational outcomes.

**Stereotype Threat**

In recent years, researchers have investigated the impact of stereotype threat on educational outcomes for underrepresented groups. Stereotype threat refers to being at risk of confirming a negative stereotype about one’s social group [10]. Stereotype threat can result in reduced working memory capacity, reduced self-control, reduced effort, changes in physiological processes, lowered performance expectations, negative cognitions and dejection, anxiety and dis-identification with academic goals [7, 11, 12]. The person experiencing stereotype threat does not need to believe in the stereotype; the risk of negative impact to performance is related to knowledge that the stereotype stands as a hypothesis [10]. Vulnerability to stereotype threat can impact any individual, but has been found to have different impacts on students based on gender and race. According to Steele [10], the experiences of African American students are uniquely influenced by stereotype threat as a result of their association with a group whose intellectual abilities have been broadly questioned. Tine and Gotlieb [13] found individuals with three levels of stigma – gender, race, and income-based stereotype threats – experienced significantly larger negative effects on math and working memory performance.

Researchers tested the stereotype threat hypothesis in real-world and lab settings and confirmed the impact of stereotype threat on standardized test scores as well as classroom performance and grades [11], [13] & [14]. Other researchers conducted meta-analysis of data from over 18,000 students in five countries and found bias resulting not from the content of academic performance measures, but from the context in which the measures are actually assessed [14]. Studies have also concluded that when stereotype threat is reduced, students in negatively stereotyped categories outperformed students from non-negatively stereotyped categories on tests and class assignments when both have the same prior academic records [11]. It is arguable that stereotype threat impairs overall academic performance and systematically underestimates ability for some underrepresented groups.
Researchers have pointed out that for many underrepresented groups, the majority of their academic experiences are in atmospheres with faculty members, administrators and other authority figures who are not from their “in group” [15] [16] & [17]. For groups with very small percentages in the STEM field, such as African American women, it is statistically less likely that these students would ever have access to a “like me” faculty member or mentor in the field without specific interventions or strategies to ensure such relationships exist. The expression “like me” in reference to faculty members, mentors and other academic and career role models is terminology borrowed from recent efforts in the nursing field. The US Health Resources and Services Administration funds the Nursing Workforce Diversity (NWD) program with the goal of increasing access to culturally competent nursing that is reflective of the diversity of the communities in which they serve; this program assists students from disadvantaged backgrounds to obtain nursing credentials [18]. A successful component of many NWD programs includes pairing future nurses with mentors who come from similar backgrounds; the ‘like me’ nomenclature is an example of the value of cross-discipline knowledge transfer in terms of overall discourse. The nursing field differs in many ways from engineering or computer science, however needs related to underrepresented populations are very similar and knowledge about what works should be transferred across these fields.

Qualitative and Quantitative Systematic Review

Translation of knowledge across fields can be accomplished using a variety of methods, to include joint research conferences and symposiums, inter-disciplinary research studies, and research methods specifically aimed at synthesizing information on a topic, regardless of discipline. Generally used by medical researchers, the qualitative and quantitative systematic review (QSR) methodologies provide a methodical and comprehensive review of relevant studies, combining the findings together in a summarized form [19]. Specific methods for quantitative and qualitative systematic reviews have been developed and continue to evolve; Seers [20] provides a summary of methods for conducting a systematic review. Snilstveit, Oliver and Vojtkova [21] contend the key principles of the QSR approach are comprehensive, systematic and transparent. Other noted advantages to this approach include reductions in research costs, broader generalizability and extrapolation of results, as well as enhanced reliability and accuracy when compared to individual studies [19]. Figure 1 illustrates the methodology in comparison to other study designs, with case reports being the least comprehensive and meta-analysis being the most comprehensive approach.

Over the past decade, a number of studies have been conducted to investigate the impact of stereotype threat on educational outcomes, as well as efforts to improve STEM degree program outcomes for underrepresented populations. QSR was selected as a methodology to comprehensively analyze these efforts in order to identify key factors associated with recruitment, retention, and related career attainment, as well as to create a framework for colleges and universities to adopt and adapt, in order to promote success in STEM programs for more students from underrepresented backgrounds.
Identification of Research Studies

Qualitative and quantitative research studies with outcomes data related to STEM recruitment, retention, degree attainment and career attainment were identified via a phased search of electronic databases. The research team collaboratively designed a QSR protocol outlining inclusion criteria for the selected studies; this protocol specified items such as the study time frame, population, intervention type, keywords, and search database. The initial phase included a database search and review of the abstracts of all peer-reviewed publications that contained keywords or alternatives as outlined in the QSR keyword concept map.
The second phase entailed a critical appraisal of each article for appropriateness, using a critical appraisal form to uniformly evaluate the studies on items such as research design, sample size, acknowledgement of limitations, researcher bias, and recommendations supported by data. Prior to appraising the articles, the researchers conducted simultaneous appraisal of a selected article, to ensure agreement on appraisal connotations and to increase inter-evaluator reliability. The researchers agreed to assign a score of 1-10 for each appraisal, with articles scored at less than five being excluded from the third phase of the QSR. The initial search phase returned a total of 54 articles that fit the QSR protocol criterion. Of that amount, 25 articles met the critical appraisal rating of five or higher, and were included in the third phase of the QSR. These articles were: [9, 11, 15, 16, 22-42].

Data Extraction and Analysis

The third phase of this QSR entailed a comprehensive review and extraction of findings from the 25 studies. A data extract form specified items to be documented for each study, including participants and type, study context, outcomes assessed, interventions, objectives, findings and results, and recommendations. Data from the extraction forms was entered into a Microsoft Access database for analysis. The research team then set two rules for an iterative process to translate themes and concepts from the extracted data; the themes and concepts were derived from the actual results and findings as documented in the database and, if noted in nine or more of the studies then themes and concepts formed a synthesis topic. The research team then conducted backward mapping to re-count instances of each theme and concept finding across all studies. The four synthesis topics of identification, environment, capitals, and process were identified during this iterative procedure, with distinct categories of findings assigned to each topic.

Findings

Evidence from this systematic review of studies supports the contention that undergraduate STEM programs can indeed play a significant role in terms of solutions to problem of underrepresented populations in the STEM profession. Findings suggest there are four distinct areas factors associated with improving recruitment, retention, and related career attainment in STEM fields for undergraduate students from underrepresented backgrounds, and within those areas, specific actions colleges and universities should undertake in order to reduce the negative impact of stereotype threat and promote success in STEM programs for more students from underrepresented backgrounds.

Implicit across all of the studies was the essential influence of leadership, data, development and reporting. Taken together, these findings suggest that certain approaches must be embedded into the overall fabric of the institution in order to achieve equitable education outcomes. Institutional fabric and campus environment are shaped not only by what is written in official policy, but by what is actually practiced on a regular basis. Individuals at every level of institutional leadership (academic and administration) must take a proactive and intentional approach to equity in educational outcomes. These approaches can be operationalized in terms of data-driven decisions, faculty and staff development, as well as reporting.
Table 1: Synthesis of Findings

<table>
<thead>
<tr>
<th>Synthesis Topics</th>
<th>Categories of Findings</th>
<th>Findings Count (# of times indicated in each study)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identification</td>
<td>- Focus on goal orientation</td>
<td>23</td>
</tr>
<tr>
<td></td>
<td>- Provision of research experience</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Support for multi-cultural / simultaneous ID development</td>
<td></td>
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<tr>
<td></td>
<td>- Support for scientific ID development</td>
<td></td>
</tr>
<tr>
<td>Environment</td>
<td>- Aware and supportive faculty</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>- Supportive campus/welcoming to underrepresented populations</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Supportive community for specific groups</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Supportive STEM discipline/program units</td>
<td></td>
</tr>
<tr>
<td>Capitals</td>
<td>- Aspirational capital development</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>- Cultural capital acknowledgement and development</td>
<td></td>
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<tr>
<td></td>
<td>- Navigational capital development</td>
<td></td>
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<tr>
<td></td>
<td>- Social capital development / ‘like-me’ mentors</td>
<td></td>
</tr>
<tr>
<td>Process</td>
<td>- Eliminating “weeding out” courses and practices</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>- Looking for resilient students, instead of ‘scientists’</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Smoothing out the transfer process for community college students</td>
<td></td>
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<td></td>
<td>- Use of communication strategies</td>
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<td></td>
<td>- Use of STEM course syllabi as a tool for engagement</td>
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</table>

**Framework for Colleges and Universities**

This study used the aforementioned factors to develop a framework for colleges and universities to adopt and adapt, in order to promote success in STEM programs for more students from underrepresented backgrounds. Three distinct sections are illustrated in the proposed framework; first, the Campus Environment and role of institutional action in mitigating stereotype threat is shown; then examples of Evidence-Based Practices to mitigate stereotype threat, enhance scientific ID development, expand capitals, and enhance STEM program processes are provided; and lastly, potential STEM Program and Workforce Outcomes are presented.
Discussion

One of the most interesting aspects of the study was the use of a research methodology, QSR, not commonly employed in STEM disciplines. An evidence-based research methodology, QSR is commonly employed in medical disciplines. Though distinct in many ways, medical and STEM disciplines share many commonalities, including the need for evidence-based approaches.
facilitating the study of complex human-centric systems, such as workforce homogeneity. The QSR methodology was an effective guide for our study, enabling it to be conducted in adherence to well established research practices and guidelines. Additionally, it allowed us to evaluate employment of an approach novel to the STEM discipline with an eye toward future studies.

Easily the most interesting outcome of the QSR was the importance of student identification in improving recruitment, retention, and related career attainment in STEM fields for undergraduate students from underrepresented backgrounds. Of the 25 peer-reviewed journal articles analyzed through the QSR process, sense of identity permeated 23. It is very important to contextualize this category of findings in terms of stereotype threat, which is by definition linked to sense of identity; this threat is quite literally the function of a negative aspect of one’s group identification. Our findings indicate this negative aspect of identity is commonly being countered in real-world learning environments by the fostering of positive group identification; however, as often as not, administrators and educators do not realize why their efforts and interventions succeed.

The Stereotype Threat Reduction Framework (STRF)

The STRF is designed to assist college educators and administrators understand the various mechanisms used to mitigate stereotype threat in undergraduate students; the goal being to promote success in STEM programs for more undergraduate students from underrepresented backgrounds, and ultimately increase their representation in STEM career fields. The STRF helps educators (administrators, faculty and staff members) understand how and why instructional pedagogies, such as collaborative learning, and academic initiatives, such as faculty-student mentoring, work. It helps university administrators visualize a more complete STEM pipeline, from recruitment through career. It impresses the importance of fostering not simply the development of a single sense of identity in students, but of fostering the development of a multitude of non-exclusive, complementary senses of identity that reflects in each individual student their discipline (i.e., scientist, engineer), culture, gender, ethnicity, socioeconomic background, veteran status, etc. Explicitly identified in the STRF is the importance of faculty-student and mentor-student interactions on the development of student sense of identity, particularly those with “like me” faculty members and “like me” mentors. Finally, the STRF details the importance of reframing many of our existing instructional scaffoldings from an orientation of deficiency-remediation to professional-development with regard to the development of student identity.

Study Limitations and Delimitations

As follow-up to a small-scale pilot study, this investigation was designed to be of incrementally larger, yet still moderate, scope. As such, the literature included in the QSR was limited to articles published in peer reviewed journals. Conference proceedings, regardless of the discipline or reputability of the conference, were not included in the study. Literature included in the QSR were also limited to articles identified via search of only 11 predetermined databases, identified in the QSR protocol. As noted in the methodology, the initial search phase returned a total of 54 articles that fit the QSR protocol criterion. Of that amount, 25 articles met the critical appraisal rating of five or higher, and were included in the third phase of the QSR. Finally, the current
QSR does not incorporate an assessment of relative degree to which articles reflect each of the four factors identified in the study (i.e., identification, environment, capitals, processes); instead, the QSR simply protocol simply identifies whether the article does or does not reflect each factor.

Next Steps

To increase confidence in the findings of this study, as well as tease out additional insights, the researchers feel that a study of larger breadth needs to be performed. Specifically, the breadth of the QSR needs to be increased to include a larger number of articles drawn from a wider array of databases. Additionally, the study should evaluate articles cited by those already in the QSR, incorporating those articles that meet the QSR protocol criterion for inclusion in the study. Finally, the revised study should develop and subsequently incorporate a means to assess the relative degree each article reflects each factor identified in the study (i.e., identification, environment, capitals, processes).
References


Stemming Stereotype Threat: Recruitment, Retention, and Degree Attainment in STEM Fields for Undergraduates from Underrepresented Backgrounds

Najmah Thomas, PhD; Ron Erdei, PhD

2018 The Collaborative Network for Engineering and Computing Diversity (CoNECD) Paper Presentation / Workshop Session Outline

Background & Literature Review:

- Grounding diversity conversations in context of innovation and global competitiveness
- Developing a deeper understanding of the opportunities for improvement in terms of STEM education programs and STEM workforce diversity
- Focusing attention on connections between stereotype threat and STEM education program outcomes for underrepresented populations

QSR – Why Qualitative/Quantitative Systematic Review?

- The value of cross-discipline knowledge transfer
- Methodical review of promising practices, comprehensive analysis of findings
- Identification and classification of key factors

How the Current Study Employs QSR:

- Methods – QSR protocol and keyword concept map, critical appraisal, and data extraction
- Analysis - Iterative translation of themes and concepts, backward mapping
- Initial Findings – identification, environment, capitals and process

Stereotype Threat Reduction Framework (STRF): An Adaptable Tool for Colleges and Universities:

- STRF is a new framework derived from the findings of the QSR analysis, describes a proposed theory of change for reducing stereotype threat in academic settings
- Desired/anticipated change is increase in successful STEM education program outcomes for underrepresented students, leading to increased representation and diversity in STEM workforce
- STRF helps educators understand how and why certain strategies work, visualize a more complete STEM pipeline with their roles clearly identified
- STRF connects institutional environments and practices such as “like me” mentors and faculty to elements such as identification development for STEM students
- Three areas illustrated in the framework:
  - campus institutional fabric & role of institutional actors in mitigating stereotype threat
  - examples of evidence-based practices to address stereotype threat
  - potential STEM program and workforce outcomes
- STRF offers a new perspective on the topic of inclusion and transforming institutional leadership in undergraduate STEM programs
- STRF also has strong potential to transfer in other academic programs