Systematic Review

A Systematic Review of Barriers to Accessing Undergraduate Research for STEM Students: Problematizing Under-Researched Factors for Students of Color

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Abstract: While the benefits of undergraduate research experiences for students from underrepresented racial/ethnic groups have been well explored, more research is needed to better understand how students of color access these experiences. We summarize a non-structured review of literature that highlights barriers to success that students of color face in relation to STEM programming at the postsecondary level. Building from this, we report on a structured review of barriers to accessing undergraduate research. We discuss implications of the relative lack of research on access to undergraduate research for students of color at postsecondary institutions. We consider how barriers for the success and persistence of students of color in postsecondary STEM, overall, may manifest as barriers to accessing the undergraduate research experiences argued to help reduce these barriers. With the hope of guiding future relevant action, we put forth recommendations for researchers and practitioners.

Keywords: undergraduate research; access; STEM

1. Introduction

In 2012, the President’s Council of Advisors on Science and Technology (PCAST) argued for the need for an additional one million science, technology, engineering, and mathematics (STEM) professionals in the US, equivalent to an increase of 34% each year of undergraduate STEM degree conferrals (President’s Council of Advisors on Science and Technology 2012). This larger STEM workforce is needed to maintain a reputation for excellence in science and technology in the US, as well as meet the nation’s evolving needs around increasingly complex socioscientific problems (Hewitt et al. 2019). Scholars have recognized that prominence and diversity in STEM are closely intertwined (Hong and Page 2004; Page 2008), and increasing the representation and success of students of color in STEM career pathways has been a priority in the United States for decades (Hurtado et al. 2010). Yet students that identify as Latino/a, Black/African American, and American Indian/Alaska Native still remain underrepresented in U.S. science and engineering bachelor’s degree programs when compared to their college-aged majority-group peers (National Science Foundation 2018).

The heightened sense of competition, large class sizes, and limited student-faculty interactions in postsecondary science and engineering programs make it challenging for many students to complete a STEM degree, regardless of race or ethnicity (Baldwin 2009). However, for students of color, race/ethnicity-related barriers may introduce additional challenges. For example, research has shown that students from historically underrepresented racial/ethnic groups in STEM experience stereotype threat, or anxiety that arises when one expects to be evaluated based on negative stereotypes; such threat has a positive, significant effect on attrition from postsecondary STEM programs (Beasley and Fischer
Students of color who are also women, first-generation college students, low-income students, or students identifying as LGTBQ+ must navigate multiple systems of oppression simultaneously, per the intersectionality of their social identities (Ong et al. 2011). Regardless of some students succeeding, Ong (2005) found that women of color had to engage in a considerable amount of added social and psychological work to persevere in physics undergraduate and graduate programs through strategies such as enacting social identities that felt false to them.

In response to concern over a lack of diversity in STEM postsecondary programs, and equity in experiences, institutions of higher education across the nation have promoted a set of “high-impact practices”, shown to enrich student experiences and success, especially for students from groups historically underrepresented in postsecondary institutions (Kuh 2008). One of these high-impact practices is the faculty-mentored undergraduate research experience, wherein students engage in discipline-based inquiry/research/scholarship activities in collaboration with expert faculty mentors. For example, an undergraduate may be trained by a faculty mentor to conduct a small-scale study of how DNA methylation is associated with telomere length as a part of the mentor’s larger research agenda. Undergraduate research experiences can take many forms (see a recent National Academy of Science, Engineering, and Medicine (NASEM) (2017) report on the successes, opportunities, and challenges of undergraduate research experiences for STEM students highlighting eight different forms). Two of the most common types are apprentice-style research experiences and course-based undergraduate research experiences (CUREs).

Within the apprentice-style model of undergraduate research, a student (or small group of students) works closely with an experienced faculty mentor to investigate outside the classroom a question(s) appropriate and meaningful to a discipline. Many researchers have documented student gains resulting from these experiences. Hunter et al. (2007), via an ethnographic study of students and faculty engaging in a summer apprentice-style research program, found that both mentors and mentees perceived the program helped students learn to work and think like scientists, e.g., through the development of problem-solving skills and by gaining a better understanding of the nature of scientific knowledge. While CUREs typically require more planning on the part of a course instructor and more step-based and common student activities (National Academy of Science, Engineering, and Medicine (NASEM) 2017), CUREs also allow students to explore novel and appropriate disciplinary questions via inquiry, and may allow greater accessibility and inclusivity to undergraduate research per part of typical student coursework (Bangera and Brownell 2014; Pierszalowski et al. 2018).

A growing body of literature elucidates the positive effects of undergraduate research experiences, writ large, and specifically for students from historically underrepresented groups. For instance, interactions with research mentors can lead to gains in confidence and a better understanding of educational and career possibilities for African American and Hispanic students in STEM (Thiry and Laursen 2011). Other studies have reported that undergraduate research experiences provide opportunities to develop a science identity for women of color (Carlone and Johnson 2007) and increase retention rates for African American and Hispanic students (Jones et al. 2010; Nagda et al. 1998). In one investigation of an undergraduate research program designed for students from underrepresented racial/ethnic groups, participants graduated faster and with higher grade point averages (GPAs), were more likely to graduate with a science degree, and were more likely to enter a science graduate program when compared with a propensity score-matched comparison group (Slovacek et al. 2012). In response to these findings, federal agencies like the National Science Foundation and the National Institutes of Health have committed significant funding to increase the number of undergraduate research opportunities, with the ultimate aim of fostering racial/ethnic diversity in STEM and the nation’s capacity for research innovation and technological advancements (Eagan et al. 2013).

While the benefits of undergraduate research experiences for underrepresented student groups have been fairly well explored, more research is needed to better understand
how students from historically underrepresented racial/ethnic groups (Black/African American, Latino/a, Native American/Alaska Native, and/or Pacific Islander/Native Hawaiian) come to interact with undergraduate research experiences.

Consider:

Lola, a female student of color studying engineering at a predominately white institution, regularly confronts microaggressions and feelings of racial/ethnic isolation in her field, barriers shown to negatively affect her success in STEM (see Ong et al. 2017). Realizing this student would likely yield large personal and professional gains from engaging in undergraduate research experiences, a well-intentioned advisor encourages her to “join a research lab”. Yet Lola hesitates to accept the offer. Why? Might the barriers impacting Lola’s success in STEM in some way manifest as barriers in accessing a research experience? For example, might Lola’s feelings of alienation from mainstream campus culture, as illuminated by Feagin et al. (1996) in their study of African American students’ experiences at a predominantly white university, cause Lola to intentionally distance herself from extracurricular work or interactions with faculty or other researchers?

In this article we explore issues of access for students of color related to opportunities for undergraduate research. We contend there are important reasons to explore issues of access to undergraduate research for students of color at this moment in time. Such knowledge may help inspire additional work and affordances to help ensure students of color have equitable (i.e., as opposed to equal) access to opportunities like undergraduate research and the benefits these experiences may bring (Pierszalowski et al. 2018). Additionally, we see concerns with a research body overwhelmingly focused on student gains resulting from undergraduate research experiences (e.g., Hunter et al. 2007; Lopatto 2007; Russell et al. 2007). While this work is important, especially in illuminating the strong, positive personal and professional gains for students from historically underrepresented groups (e.g., Nagda et al. 1998; Slovacek et al. 2012), we argue that it does not pay sufficient attention to issues of access and inclusion. Additionally, we must consider that a research body that primarily highlights majority narratives potentially undermines the democratic ideals of education in perpetuating inequities (Solórzano and Yosso 2016; Zamudio et al. 2011). Given the limited research in this area, we consider how similar barriers for the success and persistence of students of color in postsecondary STEM, overall, may manifest as barriers to accessing the undergraduate research experiences argued to help reduce these barriers. Overall, we contribute to a growing body of work that advances the field by more intentionally considering issues of access and inclusion and moving the focus from “how do students benefit from these experiences?” to “who is able to access and benefit from these experiences?”.

The goals of this paper are threefold. First, we summarize barriers to success for students of color in relation to STEM programming at the postsecondary level using a non-structured review of recent literature. Building from this initial review, we report on a structured review of the literature that then examines barriers to accessing undergraduate research, with special attention on STEM students of color. We discuss implications of the relative current lack of focus on access to undergraduate research at postsecondary institutions, including posing a collection of questions for how barriers in the way of success and persistence in postsecondary STEM may manifest as barriers to accessing undergraduate research experiences for students of color, with the hope of guiding future consideration and action, on the part of researchers and practitioners.

2. Materials and Methods

2.1. Preliminary Non-Structured Literature Review

Given the limited research informing our larger goal of investigating barriers to accessing undergraduate research for STEM students of color, we first conducted a preliminary, non-structured literature review concerning the following research question: What barriers
exist for students of color trying to earn STEM undergraduate degrees? A barrier was conceptualized as something that contributed negatively to an undergraduate student’s success (maintaining good enough grades to remain in good standing) and persistence (remaining in postsecondary education in a STEM degree program).

We identified relevant articles through the education-related online databases, JSTOR and EBSCOhost, using search terms relating to “minority”, “underrepresented”, “STEM”, “barrier”, and “undergraduate”, as well as articles known to be relevant to the field per the first author’s experience as a coordinator of a STEM diversity initiative with a focus on undergraduate research. The lead author then surveyed a total of 38 relevant articles (Appendix A) to generate a list of potential barriers for students of color in relation to STEM at the postsecondary level. When an author(s) of an article discussed something that contributed positively to success for students of color in STEM, we did not assume its absence to be a barrier to success unless it was referred to as one by the author(s). For example, if an author(s) mentioned that having role models of a similar race or ethnicity led to GPA gains for students of color, we did not automatically assume that a lack of such role models served as a barrier for students of color unless that was explicitly mentioned in the literature (which it was). The lead author only catalogued barriers when it was explicit or implied that the author was referring to the barrier as it pertained to success or persistence for students of color during their postsecondary educational experiences. It is important to note that barriers identified during the primary non-structured review were not always backed up by empirical data in the article being reviewed; in some cases, they were only mentioned in the article, for instance as citations that the article’s authors deemed relevant. Thus, the lead author worked from an assumption that barriers mentioned in articles had been confirmed by the authors and the reviewers for that article, who are, collectively, experts in their fields.

The 38 articles that were the basis of the primary non-structured review yielded ten emergent categories of barriers to success for students of color in relation to STEM at the postsecondary level. These categories then became the basis for the structured literature search (described below) on barriers to accessing undergraduate research experiences for STEM students of color.

2.2. Structured Literature Review: Identifying Articles Addressing Barriers to UR

During the next phase of the literature review, we combined key words and phrases from the ten categories of barriers identified via the non-structured review with the search terms “undergraduate research”, “barrier”, and “students of color” to identify articles that addressed barriers in access to undergraduate research experiences (Appendix B). The lead author conducted each search using Google Scholar, which allowed us to search more holistically across multiple databases instead of just one (Zientek et al. 2018), and restricted searches to peer-reviewed journal articles published from 2000–2017, to generate a recent assessment of research-identified barriers to accessing undergraduate research that exist in higher education for STEM students of color. Given the limitations of these search dates, we situate our findings in articles published post-2017 in the discussion section.

A total of 10,093 Google Scholar search results were generated. Two authors co-screened 30 papers identified through one Google Scholar search together to determine inclusion and exclusion criteria through an iterative process that let us determine whether criteria were accurately capturing or not the articles of interest. Once inclusion/exclusion criteria were determined, the lead author screened all 10,093 articles within a ten-day period between 9/26/17 and 10/2/17, to eliminate the need for performing another search as Google Scholar evolves in its listings (Appendix B). Titles were first used to eliminate articles that did not appear relevant to this study. To pass the first phase of screening, titles had to mention or imply the study related to two or more of the following foci—a STEM field, undergraduate research, students of color, or undergraduates—without invalidating one of these foci. A title invalidated one of the foci when it explicitly stated or implied the study was not about STEM, undergraduate research, students of color, or
undergraduates (e.g., “Multiple case study analysis of young women’s experiences in high school engineering” invalidated the focus on undergraduates by indicating the study was about high school students). Titles invalidating one or more of these foci were excluded.

When a title met these inclusion criteria, the lead author also screened the abstract. If the abstract mentioned or implied the study related to a STEM field and undergraduate students of color and barriers to accessing undergraduate research, the paper was included in our analysis. We excluded papers with abstracts that did not explicitly mention or imply the study related to a STEM field and undergraduate students of color and barriers to accessing undergraduate research. When a title met inclusion criteria, but no abstract was provided or was not obvious, the lead author skied the body of the text to see if the study related to a STEM field and undergraduate students of color and barriers to accessing undergraduate research; papers then meeting these criteria were then also included.

During the review of abstracts, we noted a lack of research on barriers to accessing undergraduate research specifically for students of color in STEM. This finding motivated us to relax our inclusion criteria when reviewing articles and also consider those that implied the study related more generally to undergraduate students and barriers to accessing undergraduate research (Figure 1).

Thus, our focus widened to include barriers to accessing undergraduate research for all students. This means we were no longer solely focusing on research concerning the experiences of students of color or experiences exclusively within STEM. We also chose to include one paper that did not show up in the Google Scholar searches but that the authors knew to be relevant to this topic (Wayment and Dickson 2008). These relaxed criteria yielded a total of eight papers for analysis from the 10,093 search results.

Figure 1. Flowchart outlining the methods and outcomes of our preliminary non-structured literature review and subsequent structured literature review which led to the final number of articles analyzed.
Using these eight papers, one author conducted forward and backward searches (papers cited by or citing those eight papers) using the same relaxed inclusion/exclusion criteria (Figure 1). All forward searches were conducted within a 24-h period (6 April 2018) and yielded a total of 221 articles whose titles and abstracts were screened against our inclusion/exclusion criteria detailed above. This resulted in another 13 articles for analysis. Backward searches yielded 383 articles whose titles and abstracts were screened against our inclusion/exclusion criteria, resulting in an additional 18 papers for analysis. After the three authors analyzed these 31 total articles resulting from forward/backwards searches, we noted that 13 did not attend to our topic of interest in the body of the paper regardless of meeting our criteria during title/abstract review. Thus, our final number of articles analyzed/discussed in the remainder of the paper is 18 (Figure 1).

We acknowledge the novelty of these methods described above and recognize that we could be creating a methodological weakness by applying the ten categories of barriers for students of color that we identified in the preliminary nonstructured literature review in the structured literature review around experiences for all students in STEM. That is, we may have inadvertently failed to explore additional barriers that STEM students across demographic categories experience. At the same time, we think this paper’s offerings are still meaningful in illuminating an important set of potential barriers for all students, with newly offered implications for under-researched factors for STEM students of color. Given what we know about additional barriers for underserved groups in STEM and the national imperative to diversify STEM disciplines, we contend a methodology like ours, even with its potential limitations, allows for considerations of barriers that urgently need to be explored. We do recommend that future research examines additional factors that we may not have considered due to our methodology.

2.3. Analysis Procedure for Structured Literature Review

Two authors employed a two-phase philosophical hermeneutic approach to interpreting the text within the 18 articles identified through the structured literature review (Trede and Loftus 2010; Trede et al. 2012). This is a qualitative approach that employs critical reflexive dialogue, by posing questions and drawing answers from the text. Our analysis proceeded in two phases. First, we independently read each article and recorded individual responses to the following three questions:

1. Which barriers to accessing undergraduate research experiences are identified in the literature using original research?
2. What methods and central theories are used to explore barriers in access to undergraduate research experiences for students?
3. What implications were outlined for overcoming barriers to undergraduate research experiences for students?

We then compared results, clarified inconsistencies, and settled on a shared interpretation of the text. On the rare occasion when a result offered was not obvious in meaning, we chose not to include it (e.g., “having research-led teaching associate deans in faculties so that they can integrate research and teaching strategy”; Brew and Mantai 2017, p. 564). Our collective interpretations of the articles’ responses to these questions are presented in the following section.

3. Results

3.1. Non-Structured Literature Review

The 38 articles included in the preliminary, non-structured literature review yielded ten emergent categories of barriers to success for students of color in STEM at the postsecondary level (Appendix C).

I. Lack of representation or a lack of role models. This category included the subcategories of (1) lack of representation at all levels within the college/university, (2) the absence of culturally relevant role models and peers, and (3) being considered to act as a representative of one’s group.
II. Family and cultural barriers. This category included subcategories of (1) difficulty bridging cultural expectations and norms with expectations and norms in academia, (2) conflicting identities, and (3) absence of peer/family support or excessive peer/family pressure.

III. Psychosocial barriers with subcategories of (1) exposure to stereotypes, (2) additive psychosocial effects, (3) physical side effects of psychosocial barriers, (4) pressure and doubt from self and others, (5) feeling conspicuous, (6) lack of belonging, (7) lack of identity, and (8) feeling inadequate.

IV. Academic preparation with subcategories of (1) inadequate academic preparation and (2) lack of resources prior to college.

V. Financial barriers, which included subcategories of (1) high financial need and (2) a need to work.

VI. Institutional barriers. This was broken into subcategories of (1) issues in the classroom/curriculum, (2) campus climate, and (3) faculty issues.

VII. Lack of capital. Subcategories that emerged were (1) a lack of information and (2) inadequate human and cultural capital.

VIII. Historical barriers associated with STEM fields, including subcategories of (1) STEM cultural barriers and (2) STEM claiming to be objective or neutral in nature.

IX. Student interest, which included subcategories of (1) growing disinterest in STEM and (2) greater interest in another field.

X. Racial, including subcategories of (1) racism, (2) subtle racialized messaging, and (3) exclusion.

More detailed explanations of each sub-category, as well as examples, are provided in Appendix C. As mentioned above, these ten categories served as the basis for the subsequent structured literature search on barriers to accessing undergraduate research experiences for STEM students of color, as well as our discussion below of how STEM postsecondary contexts could manifest as challenges to securing an undergraduate research position in an effort to highlight areas of study that deserve further attention.

3.2. What Methods and Central Theories Are Used to Explore Barriers in Access to Undergraduate Research Experiences for Students?

There were some methodological and conceptual similarities shared among the 18 articles included in this review. These are summarized in Table 1. Articles we reviewed collected data from faculty (n = 6), students (n = 4), or both (n = 5). Many of the articles we reviewed employed qualitative data collection and analysis strategies, either exclusively (8) or in conjunction with quantitative methods (5). Qualitative methods were mostly individual interviews (n = 6) and/or focus group interviews (n = 5). A handful relied on quantitative strategies only (n = 5). Questionnaires or surveys were used by many researchers (n = 12 articles), with some researchers using a pre-post research design (n = 3). A couple of sets of researchers explored change over time in response to an intervention, first gathering data to inform the development of an innovation, and then studying the impacts (n = 2 articles). Ten (10) articles explored phenomena across (types of) institutions. While seven (7) articles focused specifically on STEM fields, three (3) focused more broadly across academic disciplines. Four (4) articles specifically focused on psychology and three articles (3) did not specify a disciplinary focus for their studies.
Table 1. Methodological and conceptual similarities shared among the eighteen articles included in this review.

<table>
<thead>
<tr>
<th>Article</th>
<th>Source of Data</th>
<th>Method</th>
<th>Data Collection Type</th>
<th>Discipline(s)</th>
<th>Positivist or Postpositivist Assumptions</th>
<th>Theoretical Framework</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brew and Mantai (2017)</td>
<td>faculty</td>
<td>qualitative methods</td>
<td>individual interviews</td>
<td>does not specify, although participants come from economics/business, health, arts, social sciences, and science disciplines</td>
<td>no</td>
<td>n/a</td>
</tr>
<tr>
<td>Hirst et al. (2014)</td>
<td>students and faculty</td>
<td>qualitative methods</td>
<td>student achievement data, questionnaires/surveys</td>
<td>STEM</td>
<td>no</td>
<td>n/a</td>
</tr>
<tr>
<td>Hurtado et al. (2011)</td>
<td>students and faculty</td>
<td>qualitative and quantitative methods</td>
<td>individual interviews, focus groups, questionnaires/surveys</td>
<td>biomedical and behavioral science</td>
<td>yes</td>
<td>n/a</td>
</tr>
<tr>
<td>Hvenegaard et al. (2013)</td>
<td>students, faculty, and administrators</td>
<td>qualitative methods</td>
<td>focus groups</td>
<td>fine arts, humanities, social sciences, and sciences</td>
<td>no</td>
<td>n/a</td>
</tr>
<tr>
<td>Jones and Davis (2014)</td>
<td>faculty</td>
<td>qualitative and quantitative methods</td>
<td>focus groups, questionnaires/surveys</td>
<td>does not specify</td>
<td>yes</td>
<td>n/a</td>
</tr>
<tr>
<td>Kierniesky (2005)</td>
<td>faculty</td>
<td>quantitative methods</td>
<td>questionnaires/surveys</td>
<td>psychology</td>
<td>yes</td>
<td>n/a</td>
</tr>
<tr>
<td>Mahatmya et al. (2017)</td>
<td>students</td>
<td>quantitative methods</td>
<td>questionnaires/surveys</td>
<td>life sciences, social sciences, engineering, clinical/medical sciences</td>
<td>yes</td>
<td>organizational citizenship behavior, social exchange theory</td>
</tr>
<tr>
<td>Morales et al. (2016)</td>
<td>faculty</td>
<td>quantitative methods</td>
<td>questionnaires/surveys</td>
<td></td>
<td>yes</td>
<td>organizational citizenship behavior, social exchange theory</td>
</tr>
<tr>
<td>Pérez Huber (2010)</td>
<td>students</td>
<td>qualitative methods</td>
<td>individual interviews, focus groups</td>
<td>social sciences, sciences</td>
<td>no</td>
<td>Latina/o critical race theory</td>
</tr>
<tr>
<td>Perlman and McCann (2005)</td>
<td>“departments”</td>
<td>qualitative and quantitative methods</td>
<td>student achievement data, artifact analysis, questionnaires/surveys</td>
<td>psychology</td>
<td>yes</td>
<td>n/a</td>
</tr>
<tr>
<td>Article</td>
<td>Source of Data</td>
<td>Method</td>
<td>Data Collection Type</td>
<td>Discipline(s)</td>
<td>Positivist or Postpositivist Assumptions</td>
<td>Theoretical Framework</td>
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<tr>
<td>Schwartz (2012)</td>
<td>students and faculty</td>
<td>qualitative methods</td>
<td>individual interviews, participant observation/ethnographic, questionnaires/surveys</td>
<td>STEM</td>
<td>no</td>
<td>cultural historical activity theory</td>
</tr>
<tr>
<td>Sens et al. (2017)</td>
<td>students</td>
<td>quantitative methods</td>
<td>questionnaires/surveys</td>
<td>STEM and health-related disciplines</td>
<td>yes</td>
<td>n/a</td>
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<tr>
<td>Shanahan et al. (2017)</td>
<td>faculty</td>
<td>qualitative methods</td>
<td>individual interviews</td>
<td>health, STEM, arts and humanities, and social sciences</td>
<td>yes</td>
<td>n/a</td>
</tr>
<tr>
<td>Spell et al. (2014)</td>
<td>faculty</td>
<td>qualitative and quantitative methods</td>
<td>questionnaires/surveys</td>
<td>biology</td>
<td>yes</td>
<td>n/a</td>
</tr>
<tr>
<td>Tucker et al. (2017)</td>
<td>students, industry leaders (employers)</td>
<td>qualitative methods</td>
<td>individual interviews, focus groups</td>
<td>property and construction</td>
<td>no</td>
<td>theory of students’ research preparedness</td>
</tr>
<tr>
<td>van Vliet et al. (2013)</td>
<td>other articles</td>
<td>qualitative methods</td>
<td>literature review</td>
<td>counselling psychology</td>
<td>no</td>
<td>n/a</td>
</tr>
<tr>
<td>Wayment and Dickson (2008)</td>
<td>students and faculty</td>
<td>quantitative methods</td>
<td>questionnaires/surveys, website visitation and undergraduate research participation data</td>
<td>psychology</td>
<td>yes</td>
<td>n/a</td>
</tr>
<tr>
<td>Wolkow et al. (2014)</td>
<td>students</td>
<td>qualitative and quantitative methods</td>
<td>participant observation/ethnographic fieldwork, questionnaires/surveys</td>
<td>biology</td>
<td>yes</td>
<td>n/a</td>
</tr>
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</table>
Researchers seemed to adopt positivist or post-positivist assumptions in eleven of the articles we reviewed. We noted a limited use of theoretical/analytical frameworks. Of the five articles that did put forth frameworks, only two situated their work within critical lenses. Pérez Huber (2010) employed critical race theory (specifically, Latina/o Critical Race Theory) as both a theoretical and analytical framework to explore racist nativism (e.g., defined as “the assigning of values to real or imagined differences in order to justify the superiority of the native, who is perceived to be white, over that of the non-native, who is perceived to be People and Immigrants of Color, and thereby defend the native’s right to dominance”, p. 81) and intersectionality. Mahatmya et al. (2017) situated their work in a framework of workforce diversity that privileges organizational, individual, and historical contexts as factors informing “diversity of inclusion” (p. 3) to explore the reasons students choose to participate in undergraduate research across demographic groups and institution types.

3.3. What Are the Identified Barriers to Accessing Undergraduate Research Experiences?

Numerous barriers in access to undergraduate research were identified across the 18 articles with original research.

3.3.1. Physical Resource Issues

Lack of support/resources for students on how to navigate undergraduate research. Five articles mentioned a lack of institutional resources and support to help students navigate undergraduate research as a barrier to access. For example, Wayment and Dickson (2008) noted that the lack of an informal system for advertising opportunities for research in a mid-sized psychology department stood in the way of student access to research. Mahatmya et al. (2017) surveyed students at four different higher education institutions about their reasons for not participating in research and found that students pointed to a lack of information about opportunities. The authors claimed these barriers indicate a lack of institutional support for students who might have engaged in research if additional resources were available (e.g., offering information about available opportunities, providing support in finding a mentor, and helping students prepare to secure a position).

Sens et al. (2017) added that students from rural North Dakota lacked information about the importance of undergraduate research when pursuing careers in research or health care and were not made aware of opportunities while in college. However, no data were provided to support this claim. During focus groups with students in the United Kingdom, Tucker et al. (2017) found that participants felt they needed more institutional support for preparation before they entered a required research experience. Similarly, during focus group discussions with students at a small liberal arts institution, Hvenegaard et al. (2013) added that a lack of information about directed studies courses before enrolling was a main challenge to participation. However, it is important to note that research experiences were required for students in both of these last-mentioned studies, so access was guaranteed regardless of these challenges.

Lack of financial resources for research-related supplies. Another barrier cited in the literature was a lack of financial resources to help pay for research-related supplies. Jones and Davis (2014) surveyed faculty at two different institutions and found that limited funds for research supplies were a common issue that detracted from faculty’s experience as mentors. A lack of research equipment and supplies was also highlighted by research participants in Morales et al. (2016) as something that would prevent them from serving as mentors. Some research participants in Morales et al. (2016) also noted that without conference travel funds for students and faculty, they would be unwilling to serve as mentors. During interviews with faculty mentors and their mentees, Schwartz (2012) discovered that institutional resources to support undergraduate research were so scarce that faculty sometimes utilized their personal income to fund these experiences for students.
Lack of space (n = 3). A lack of physical space was highlighted as a barrier in three articles. For example, Brew and Mantai (2017) noted that external research facilities at a large research institution in Australia are closed during the month of January, a time between fall and spring semesters at many universities, which is presumably when students could spend additional time engaging in research experiences. A lack of space was also addressed as an issue for community college faculty who were engaged in undergraduate research partnerships with community college students and faculty at four-year institutions (Hirst et al. 2014). While it meant access to larger research facilities and equipment, community college faculty expressed frustration regarding the lack of space and research infrastructure at their home institutions. A shortage of space to support undergraduate research was also noted in a review by van Vliet et al. (2013) as a challenge to mentoring specifically within counselling psychology.

Too few research opportunities available (n = 3). Sens et al. (2017) noted that too few research experiences are available in the first place, although no data were provided to support this claim. van Vliet et al. (2013) echoed this concern in their review of barriers to mentoring in counseling psychology. Mahatmya et al. (2017) surveyed students at four different higher education institutions about their reasons for not participating in research and found that students pointed to an inability to find a mentor or the fact that they applied but were not accepted into a research position, indicating that research positions are highly competitive.

Distance from resources (n = 2). Shanahan et al. (2017) found that, in the eyes of potential faculty mentors, distance from an institution and, thus, its resources, could serve as a barrier to productive mentoring relationships for students who seek undergraduate research opportunities through online platforms. In this article, faculty felt that “the mentor’s personal preferences, experience using communication technologies, and to some extent the norms of the particular discipline affected the perception of the potential for online mentoring” (Shanahan et al. 2017, p. 9).

Distance from research-related resources was also addressed as an issue for community college faculty who were engaged in undergraduate research partnerships with community college students and faculty at four-year institutions (Hirst et al. 2014). While it meant access to larger research facilities and equipment, community college faculty found it too time intensive to commute to the university to mentor students.

Lack of support personnel (n = 2). Special attention was given in the literature to frustrations with a lack of personnel to help scale undergraduate research efforts. For example, the academics interviewed by Brew and Mantai (2017) felt that the lack of a centralized undergraduate research unit on campus meant the various processes for involving students in undergraduate research across campus were uncoordinated, which led to duplication of efforts by administrators. One participant interviewed noted they could not pay tutors enough to sufficiently support students in course-based research experiences. In the context of community colleges, Hirst et al. (2014) also found that faculty were frustrated by the lack of infrastructure and institutional support to help order supplies.

Lack of resources for undocumented students (n = 1). One article addressed a barrier specific to accessing undergraduate research from the perspective of an undocumented student. In a study exploring the intersectionality of Chicana college students, Pérez Huber (2010) interviewed an undocumented Chicana student who was altogether unable to access state and federally funded programs that supported participation in undergraduate research because of her status. The author highlighted many other barriers that undocumented students face (e.g., internalization of racist nativist beliefs, discomfort and perceived hostility toward their group in educational environments, a lack of access to college financial assistance programs, and a lack of access to educational resources, including college); however, these were not explicitly considered in relation to participation in undergraduate research. While this is an important finding that deserves further exploration, it is important to note that accessing undergraduate research was not the primary focus of this article.
3.3.2. Lack of Time

**Lack of faculty time (n = 10).** Ten articles positioned faculty as gatekeepers to undergraduate research experiences and pointed to a lack of faculty time as a factor preventing faculty from serving as mentors or supporters of undergraduate research for students. For example, in one study, Jones and Davis (2014) surveyed faculty at two separate institutions (one regional liberal arts college and one Research 1 institution) and participants responded that faculty time was a major barrier in the way of providing opportunities for undergraduate research. More than 71% of active research mentors at the liberal arts college noted that time was one of their top three challenges, although this category included both faculty and student time. Faculty at the Research 1 institution noted that faculty time was a barrier across all disciplines, although it was most problematic in lab-based disciplines.

Hirst et al. (2014) and Morales et al. (2016) both found faculty saturation (i.e., a lack of time) to be a barrier for students seeking undergraduate research experiences at institutions other than their own. Wayment and Dickson (2008) also reported that faculty time (in this case, time spent managing heavy teaching loads) was a barrier to providing opportunities for undergraduate research, although it is not clear which methods were used to support this claim.

A lack of faculty time was also mentioned specifically in the context of course-based undergraduate research experiences. For example, Spell et al. (2014) found that, across institution types, a lack of faculty time to create new research experiences was the biggest barrier to implementing opportunities for research into biology laboratory classes. Both Brew and Mantai (2017) and Hvenegaard et al. (2013) supported this claim more broadly with their findings that time to effectively implement research experiences in courses was considered to be a barrier across a wide range of disciplines by both administrators and instructors. Brew and Mantai (2017) also noted that it can take a long time for new faculty to get set up to begin research, which can delay opportunities for students.

This barrier grows even more salient as the benefits of undergraduate research become more well-recognized. For example, Shanahan et al. (2017) highlighted the views of award-winning research mentors who can feel an increase in student demand for research experiences with them, a demand that they cannot meet. Through faculty interviews and a review of the literature, respectively, both Schwartz (2012) and van Vliet et al. (2013) found that faculty pressure to advance one’s career and manage competing work foci contributed to a lack of faculty time to mentor students.

**Lack of student time (n = 6).** A lack of time was also documented as a barrier to accessing undergraduate research for students in six articles. Using data from four institutions (i.e., a public doctoral university with High Research Activity based on Carnegie classification, a private doctoral university with Moderate Research Activity, a public Master’s College with high undergraduate enrollment, and a private baccalaureate college with small undergraduate enrollment), Mahatmya et al. (2017) found that time was a barrier to participation in undergraduate research for students across demographics and institutions. The authors also found that students identifying as “seniors” in academic standing selected barriers, including a lack of time, significantly more frequently than students at other standings. Hirst et al. (2014) reported that 11% (2 of 19) of community college students responding to a survey about an undergraduate research partnership program at a nearby four-year institution indicated time was a barrier to their participation. Unfortunately, the authors did not indicate whether students felt that time was a barrier to their success within the program, a barrier to their participation in undergraduate research, or both. Finally, in a study of barriers to participation in directed studies courses, which the authors defined as “1–2 semester long courses involving one-on-one instruction with a faculty mentor, and with a focus on student-led independent research” (p. 1), Hvenegaard et al. (2013) found that some students at a small liberal arts institution felt participation in these research-intensive courses was very time consuming and difficult to fit into the existing course load, especially since there were research-related tasks for students to complete before the term started.
While the articles mentioned above pointed to a lack of student time as a barrier from the student perspective, several papers reported student time as barrier from the faculty perspective, as in Jones and Davis’s (2014) study in which some faculty members at a Research I institution noted that undergraduate research experiences required, at a minimum, 15 h per week commitment from students, outside of other course/program requirements. Faculty also indicated that students who were unable to devote this amount of time (those students dubbed “drive-by researchers”) were not encouraged to engage in research, since time devoted to a research project appeared to serve as a reflection of a student’s dedication to research more broadly. However, it was unclear whether faculty research participants themselves were not encouraging these students or whether they were referring to faculty at large as being responsible for not encouraging participation of “drive-by researchers”. Jones and Davis (2014) also found that timely completion of scientific writing and research methods courses were central to successful placement into research positions, adding more time constraints on students. Time as a barrier for students also appeared in van Vliet et al.’s (2013) review of literature on mentoring in counseling psychology. Similar to Jones and Davis (2014) assertion above, van Vliet et al. (2013) outlined one paper which recognized that academic obligations and obligations outside of school detract from the time one can commit to research activities. Finally, Brew and Mantai (2017) interviewed twenty academics with an interest in developing undergraduate research opportunities and found that some felt the shortness of semester breaks meant there was not enough time for students to engage in research projects.

3.3.3. Lack of Faculty Incentives

Lack of compensation for teaching (n = 6). In a study regarding course-based undergraduate research (CURE) experiences by Hvenegaard et al. (2013), instructors indicated the lack of remuneration to be a concern. In this same study, administrators also noted that developing a system for faculty compensation was a challenge. Kierniesky (2005) found that across institutions with differing levels of selectivity, few faculty respondents reported extra compensation for engaging students in undergraduate research and few indicated it was established as part of their regular teaching load (11.7% and 37.2%, respectively). Over half of respondents (53.7%) indicated that engaging students in undergraduate research was done as overload. In a review of the literature on mentoring within counseling psychology, van Vliet et al. (2013) reported that a lack of incentives in the form of teaching credits served as a barrier to offering opportunities for undergraduate research. This lack of compensation for heavy teaching loads was echoed as a concern by Wayment and Dickson (2008) when considering barriers in access to undergraduate research within a mid-sized psychology department, although their methods for establishing this claim were not clear. In a study exploring the extent of research-based psychology coursework across the nation, Perlman and McCann (2005) noted that faculty did not often receive teaching credit for overseeing research-based courses. Interestingly, faculty were least likely to receive teaching credit for special topics and advanced research courses, those that were most likely to emphasize research as their primary objective. Most of these were taught as overload. Research participants in Morales et al. (2016) also noted a lack of reassigned faculty time and teaching credit would prevent them from serving as mentors.

Lack of faculty recognition/promotion and tenure guidelines rewarding mentoring (n = 4). Jones and Davis (2014) found that faculty uncertainty around how mentoring was assessed within the promotion and tenure system was prevalent at both teaching-focused and research-focused institutions. Schwartz (2012) expanded on this in reporting that faculty felt compelled to wait to mentor undergraduates until after tenure was granted because mentoring would not contribute to their professional advancement. In a review of the literature on mentoring within counseling psychology, van Vliet et al. (2013) report that no recognition within promotion and tenure guidelines, a lack of incentives in the form of few resulting publications, and no awards all served as barriers to offering opportunities for undergraduate research. Research participants in Morales et al. (2016) also noted a lack of
recognition in the form of reduced service obligations would prevent them from serving as mentors.

Lack of financial incentives in summer (n = 2). In one study, community college faculty reported that insufficient financial incentives were a barrier to mentoring their own students in a partnership program with researchers at four-year institutions during summer (Hirst et al. 2014). Here, faculty participants indicated they could make twice as much money teaching two courses during summer, which would span the same time period as the partnership program. In another study, Morales et al. (2016) found that a lack of summer faculty stipends would prevent some faculty respondents from serving as mentors.

Lack of faculty competency and need for professional development related to undergraduate research (n = 2). Brew and Mantai (2017) reported that some academics felt “academic attitudes/mindsets and lack of knowledge or skills of how to implement research-based learning” (p. 557) was a key constraint in implementing research experiences for undergraduates. This was combined with participants’ concern that faculty should be attending professional development sessions to improve their understanding of how to effectively offer undergraduate research experiences but were unwilling to participate, possibly due to what the authors refer to as ‘academic arrogance’. In addition, research participants in Morales et al. (2016) noted that without the development of faculty learning communities and faculty (and student) professional development workshops, they would be unwilling to serve as mentors.

Personal/emotional costs to faculty (n = 1). Schwartz (2012) alluded to personal and emotional costs to faculty offering opportunities for undergraduate research. In this article, faculty interviewees noted that caring deeply about and supporting young students of color, especially towards helping students build identity and confidence (i.e., by talking with them about professional but also personal issues) was hard work. Despite this hard work, faculty felt there was no institutional commitment to offer additional support, including financial support, to students and faculty engaging in undergraduate research partnerships. When combined with other professional and financial costs, faculty felt that these costs outweighed the benefits of mentoring students of color, causing mentors to take fewer, or no additional students.

3.3.4. Student and Faculty Perceptions of Lack of Student Readiness to Participate in Undergraduate Research (n = 9)

One frequently addressed barrier to accessing undergraduate research across the articles was a lack of student research readiness. Mahatmya et al. (2017) for example, used a multi-institutional survey of students and documented a lack of research readiness on the part of students that prevented them from engaging in undergraduate research. Specifically, across institutions and demographic groups, first year students were more likely to indicate lack of readiness as a barrier, even though first- and second-year students were more interested in participating in undergraduate research than juniors and seniors. Via focus groups with students, Tucker et al. (2017) reported that students felt that they had low confidence and a lack of ability to do research; however, it was not clear in this study whether this low confidence and lack of preparedness prevented students from participating in undergraduate research or whether students were already participating, in which case this is more of a barrier to success within an undergraduate research experience than one to accessing the experience itself.

Several articles addressed a lack of student preparation from the faculty perspective. For example, in the context of course-based undergraduate research, Hvengaard et al. (2013), reported that instructors felt students were unprepared and administrators noted a lack of student academic ability or ability to work independently was a barrier to effective implementation of directed studies courses. Brew and Mantai (2017) also found that academics felt some students were not ready to engage in research, especially those who were struggling academically. The authors made the point that a lack of research readiness came with safety and health concerns. Jones and Davis (2014) found that faculty at two separate higher education institutions, a regional liberal arts college and a Research 1
institution, were selective about the students they brought into their research teams and that student quality and preparation/performance in class was critical. In this study, faculty from both institutions expressed issues with student preparation toward facilitating successful research experiences. Research participants in Morales et al. (2016) noted a lack of pre-training of undergraduates would prevent them from serving as mentors. A lack of student preparation for research experiences in introductory biology laboratories was also cited by Spell et al. (2014) as a key barrier cited by faculty across institution types, but most prominently in two-year colleges, minority-serving institutions, and public institutions.

In a program evaluation article outlining a health sciences-related undergraduate research program, Sens et al. (2017) highlighted the fact that rural high school education does not prepare students for undergraduate research experiences. However, no data were provided to support this finding. Finally, van Vliet et al. (2013) highlighted several articles in counseling psychology that pointed out that undergraduates do not have the same level of research skills as graduate students, which meant faculty are required to invest more time when working with them.

3.3.5. Student Lack of Interest in, and Motivation for, Participation in Undergraduate Research (n = 8)

A lack of student interest in research was addressed in several articles. For example, during focus groups, Tucker et al. (2017) found that students studying property and construction in the United Kingdom expressed a need to be interested in the work to successfully engage in undergraduate research. Mahatmya et al. (2017) found that a lack of student interest served as a barrier to access to undergraduate research for students, especially for those not already planning to participate. In a review of literature on mentoring undergraduate researchers in counseling psychology, van Vliet et al. (2013) summarized one article that identified a lack of interest in a specific topic as a barrier preventing students from mentorship opportunities (Lei and Chuang 2009). van Vliet et al. (2013) made the point in their article that scholars should work on making the field of counseling psychology more relevant to undergraduates in order to foster interest in research in this field.

Several articles pointed to the fact that research is overly intimidating and stressful for students. van Vliet et al. (2013) reviewed an article that found 14 doctoral students in counseling psychology felt that research was difficult, lonely, anxiety-provoking, and not relevant enough to clinical practice (Moran 2011). While this research did not provide evidence about realities for undergraduate students, van Vliet et al. (2013) alluded to the fact that these feelings likely persist during those years as well. Hvenegaard et al. (2013) added to this sentiment more generally with their finding that students participating in directed studies courses at a small liberal arts institution viewed the research presentation requirement (just one component of the research experience) as very stressful and intimidating. Intimidation by research appears to extend to interactions with research faculty. Using senior exit surveys, Wayment and Dickson (2008) found that psychology students felt too intimidated to approach faculty about undergraduate research at all, or approached faculty after an opportunity had passed.

Hurtado et al. (2011) visited five college campuses (two primarily white institutions, two Hispanic-serving institutions, and one historically black college/university) and interviewed students, faculty, and administrators from undergraduate science research programs. The authors also found that students felt intimidated by the idea of approaching faculty, although this finding was not directly tied to the context of approaching faculty with the intention of participating in undergraduate research. The authors did mention, however, that students paid attention to cues from faculty about approachability and used those cues to make decisions about reaching out to faculty outside of class, which could translate into a barrier to accessing undergraduate research.

Not having a curricular requirement for all students to participate in undergraduate research was also noted as an institutional barrier to accessing these opportunities. For example, academics interviewed by Brew and Mantai (2017) viewed the lack of formal
requirement for students to engage in research as one example of an institutional structure that constrains development of undergraduate research programming. In a second study that explored the prevalence of research-based experiences in psychology courses across the nation, questionnaires revealed that 21% of the 203 psychology departments that responded did not require that undergraduates participate in a research-based course (Perlman and McCann 2005). Of course, this percentage varied according to the institution type, with a greater percentage of departments at four-year institutions requiring a research-based course than the two-year institutions.

Finally, in a review of articles addressing the benefits and challenges of mentoring undergraduates in counseling psychology, van Vliet et al. (2013) highlighted one paper (Moran 2011) that found students had ambivalent or negative feelings toward research in this field, likely because it is more practice-based than research-based, and point to several other papers that suggest undergraduates are not as research-ready as graduate students.

3.3.6. Student Financial Constraints (n = 7)

Financial constraints were highlighted as a key barrier to participation for students in undergraduate research across several of the articles. When surveying undergraduates at four higher education institutions about barriers that prevent them from participating in undergraduate research, Mahatmya et al. (2017) found that 61% of students pointed to what the authors label as instrumental barriers, which included a “need to earn sufficient income during the academic year” (p. 6). The authors also found that seniors selected instrumental barriers significantly more frequently than students at other levels within their degree programs.

In another study, community college students who had participated in an undergraduate research partnership program with a nearby four-year college indicated the lack of pay impeded their participation. A faculty member surveyed in this study added that, “Other students have chosen not to participate in summer research more generally because the summer research stipend does not equal what they could earn at other jobs—income that is necessary to support more diverse family structures and greater financial needs than the traditional students [at the 4-year institution]” (Hirst et al. 2014, p. 15). van Vliet et al. (2013) mentioned one article in their literature review on mentoring in counseling psychology that pointed to financial constraints, including the fact that research coursework can mean additional fees, serving as a barrier to engaging in undergraduate research (Lei and Chuang 2009). Finally, in trying to encourage participation in an undergraduate research program for students in rural North Dakota, Sens et al. (2017) noted that low student compensation served as an obstacle. However, there were no data provided to support this claim.

Several articles highlighted that financial resources to help pay for student stipends were missing at their institutions. Jones and Davis (2014) surveyed faculty at two different institutions and found that limited funds for student stipends were a common issue that detracted from faculty’s experience as mentors. van Vliet et al. (2013) pointed to a lack of funds to support undergraduate researchers as one barrier in their effort to better understand challenges to mentoring specifically within counseling psychology. Morales et al. (2016) detailed that 42.4% of their faculty respondents claimed that without stipends for students visiting from other institutions, they would not agree to serve as mentors. Brew and Mantai (2017) interviewed academics and also found that money was a key constraint in implementing undergraduate research, although it is not clear whether academics were referring to financial incentives for faculty or financial support for student research.

3.3.7. Lack of Undergraduate Research in Courses or Issues with Implementing Undergraduate Research in Courses (n = 5)

A number of articles pointed to poorly executed course-based research experiences, or issues with implementing undergraduate research in courses, as barriers to student access to research. For example, instructors teaching directed studies courses at a small liberal arts institution felt that the lack of specific guidelines and standards for teaching them were a primary challenge (Hvenegaard et al. 2013). Administrators that were interviewed in this
same study felt that one of the greatest challenges for instructors was defining the scope of a project and properly assessing student performance. Administrators admitted to their own set of challenges, including the ability to address instructor workload or compensation and consistently assessing directed studies courses. None of these barriers were actually detailed by authors in ways that indicated they were barriers to access; however, we assume that these perceptions stand in the way of scaling these offerings so that additional students can access them. Wolkow et al. (2014) extended these findings into the context of two-year institutions. In this study, student and instructor evaluations of an introductory biology course revealed that students, instructors, and support staff required instructional resources that were more customized for their needs and that students, instructors, and support staff could have used additional training while the course was being implemented. The authors found several other barriers associated with offering successful course-based undergraduate research experiences at the community college level, including a disconnect between lecture and lab content, lack of student comfort with lab equipment, and the fact that the course felt too rushed. While these may be seen as barriers to success in course-based undergraduate research experiences, and not access, they point to reasons why it is difficult to offer these experiences at community colleges altogether.

In another study, Brew and Mantai (2017) found that academics perceived large class sizes, complex ethics processes, and a lack of time in the curriculum to implement inquiry-based learning to all serve as barriers to offering course-based research experiences. These academics also indicated that instructors lacked interest, knowledge, and compensation to effectively support inquiry-based learning in the classroom. While surveying psychology departments across the nation to better understand the extent of course-based research opportunities available to undergraduates, Perlman and McCann (2005) found that departments at several institution types had limited number of faculty members, indicating that few faculty members were available to teach research skills. The authors also noted that psychology research courses were mostly reserved for older students, which limits access for earlier-career students, and found that “40% of all courses had a research project of less than two weeks’ duration, suggesting that students experience a lot of very brief research” (p. 11).

Spell et al. (2014) explored barriers to implementing research experiences into introductory biology laboratory courses. The authors surveyed biology faculty members at different institution types across the nation and found that the most important barrier across institution types was a lack of time for faculty to design new research experiences. Cost, class size, and a lack of student preparation were the most important barriers reported at two-year institutions. For research universities, the most important barriers were class size and the number of class sections. At minority-serving institutions, the most important barriers were cost, lack of student preparation, instructor resistance, and a lack of administrator support. Finally, the most important barriers at public institutions were class size, the number of class sections, and a lack of student preparation. Additional barriers listed in free responses fell into multiple, small categories (n = 22), including time for implementation, logistics, student attitudes, connection with lecture, creativity, and curricular resources, which suggested a strong contextual influence on implementation of authentic research experiences.

3.3.8. Other Social Deterrents for Students and Faculty (n = 4)

Four articles alluded to social influences on students and faculty serving as barriers to participation in undergraduate research. Mahatmya et al. (2017) found that students surveyed across four higher education institutions indicated that social barriers (“e.g., I don’t know anyone who has done research”, p. 6) prevented them from participating in research. In their review of articles addressing the benefits and challenges of mentoring undergraduates in counselling psychology, van Vliet et al. (2013) highlight Lei and Chuang’s (2009) finding that job, family, and social commitments also stood in the way of being mentored in research. As van Vliet et al.’s (2013) article is a literature review, we
assessed Lei and Chuang’s (2009) finding more closely and found that the authors were alluding to the fact that students’ perceived obligations related to jobs, family, and social life, and academics all impose constraints on a student’s time which could delay a student’s progress in research, and potentially delay graduation if completion of a research project is required to finish one’s degree.

Brew and Mantai (2017) found that, in certain departments, a lack of interfaculty communication about engaging students in undergraduate research prevented the exchange of views about possibilities for expanding and improving the quality of research experiences, leading to fewer opportunities. Finally, in the context of course-based undergraduate research, Hvenegaard et al. (2013) revealed that instructors felt that interpersonal/communication issues with students were a challenge to implementation of successful research experiences in the classroom.

3.3.9. Negative Faculty Perceptions Regarding Student Capacity/Competency (n = 3)

Several researchers argued that faculty perceptions of student capacity and competency served as a barrier to students’ access to undergraduate research. Whereas the previous category relates more to social constraints, including social pressures and a lack of social interaction/communication, this category focuses more on the negative ways in which faculty perceive students. For example, in Brew and Mantai (2017), faculty noted that undergraduate research was not appropriate for those who were not performing well academically, did not have a good attitude towards research, or did not understand the relevance of research. Jones and Davis (2014) echoed these findings in reporting on their interviews with faculty at two different institution types, a regional liberal arts college and a Research 1 institution. In this study, faculty from both institutions expressed issues with student quality and commitment toward facilitating successful research experiences. The faculty interviewed by Shanahan et al. (2017) took this one point further in positing that some students from historically underrepresented groups have lower academic records, which could impede their access to undergraduate research. In this context, the faculty who were interviewed hoped that faculty would move past this requirement and accept students with average grades.

3.3.10. Lack of Institutional Commitment to Undergraduate Research (n = 3)

It is important to identify the distinction between barriers that place the agency on faculty and those that place agency on the institution. Ultimately, there were several researchers who emphasized agency of the institution, in essence processes/structures that happen at the institutional level, as creating barriers to accessing undergraduate research. Both Brew and Mantai (2017) and Jones and Davis (2014) made the point that rewarding faculty research over mentoring and teaching sends the message to faculty that little value is afforded to the latter two experiences by the institution. Taking a broader perspective on the lack of institutional commitment to undergraduate research, Schwartz (2012) found that many faculty members felt their institution lacked a vision to support a larger culture of research, either through partnering with larger research universities with more robust resources or by acknowledging and supporting the work that faculty were currently doing to support students in research by providing funding.

3.3.11. Student Lack of Awareness of Undergraduate Research Benefits and Opportunities (n = 3)

In a previous section, we outline that lack of support and/or resources to help students navigate undergraduate research served as a barrier to accessing these experiences. Other articles pointed to the fact that students were simply unaware of the benefits of undergraduate research, or the existence of opportunities themselves, which served as another barrier to participation. For example, during student focus groups, Tucker et al. (2017) noted that the benefits resulting from research were discussed relatively few times, indicating students were largely unable to identify reasons for participating. Wayment and Dickson (2008) identified several key barriers that related to this lack of student awareness
within the psychology department at Northern Arizona University: (1) students were not aware of the benefits of undergraduate research opportunities until too late in their undergraduate programs; (2) there was a lack of student awareness of undergraduate research opportunities, or unequal awareness, caused by a lack of formal system for advertising opportunities; and (3) student successes or products resulting from undergraduate research experiences were not being properly publicized to promote involvement. In a review of relevant literature, van Vliet et al. (2013) detailed more broadly a lack of student awareness of the field of counseling psychology that prevents students from participating, or even realizing they can participate, in undergraduate research related to this discipline.

3.3.12. Lack of Faculty Diversity (n = 2)

Interestingly, only one article addressed a lack of diversity as an institutional barrier to accessing undergraduate research. Specifically, van Vliet et al. (2013) highlighted several articles in their review that point to the lack of diversity among counseling psychology faculty. The authors positioned this lack of faculty diversity as a barrier to student access to undergraduate research by pointing to the literature that supports the idea that students often prefer mentors from similar gender and racial/ethnic backgrounds and may be deterred from these experiences by a lack of diversity among potential mentors. One faculty program director interviewed by Hurtado et al. (2011) felt that faculty inaccessibility was exacerbated by the scarcity of science faculty from historically underrepresented groups. The director highlighted that “there are very few professors who share [students’] background, so there might be something... off-putting or intimidating about a department where they never see anyone who looks like them who made it” (p. 571). However, it was not clear in the text whether this barrier relates to accessing faculty in general, or accessing mentors for undergraduate research experiences.

3.3.13. Discipline-Specific Barriers (n = 1)

In their review of barriers to mentoring in counseling psychology, van Vliet et al. (2013) highlighted that a struggle for recognition of their discipline as research-rigorous prevented students from engaging in research. A lack of visible student-faculty partnerships with other departments was also highlighted as a barrier related to a lack of research infrastructure in counseling psychology.

3.4. What Implications Were Outlined for Overcoming Barriers to Undergraduate Research Experiences for Students?

Here, we found that implications put forth by authors were largely positioned as recommended strategies for overcoming barriers to accessing opportunities for undergraduate research, which emanated from their research findings.

3.4.1. Curricular Implications

The authors of six articles highlighted the importance of CUREs for broadening participation in undergraduate research since these offerings allow for additional opportunities for student inquiry. For example, Spell et al. (2014) pointed out that faculty struggle to balance teaching and research identities and one way of overcoming this is by integrating the faculty’s research agenda into the curriculum. Shanahan et al. (2017) also mentioned that offering undergraduate research experiences within courses should be prioritized. Brew and Mantai (2017) took this a step further by pointing out that growing a culture of evidence-based teaching practices would mean additional opportunities for students to participate in the types of inquiry that are characteristic of undergraduate research experiences. The authors indicated that students would be motivated to engage in undergraduate research if academic credit was offered as an incentive and that examples of offering undergraduate research for credit should be provided.

Other implications highlighted by Brew and Mantai (2017) that would serve to promote course-based undergraduate research experiences include the creation of three-hour periods for lecture, introducing ‘flipped’ classrooms which provide time for inquiry-based
learning, and developing a facilitated program to support the creation of courses that integrate research. The authors also point out that curricular implications such as those noted above would be most effective when paired with associated policies like simplifying ethics requirements and requiring faculty to submit proposals for new course-based undergraduate research experiences. Exposure to this type of inquiry in the classroom could inspire students to seek out additional inquiry-based undergraduate research opportunities outside of the classroom.

Wolkow et al. (2014) suggested institutions help faculty and support staff become more comfortable implementing CUREs at two-year institutions, which include a large proportion of STEM students of color and those from a low socioeconomic status. The importance of this implication was echoed by Hirst et al. (2014) who also called out a need for additional support to promote CUREs at two-year institutions in order to increase access and inclusion.

Perlman and McCann (2005) outlined several implications for expanding access to undergraduate research opportunities, especially through course-based offerings. Specifically, the authors called for the promotion of psychology programs that required undergraduate research, offering and requiring more courses wherein undergraduate research is central, and offering more robust undergraduate research experiences, where students work alongside faculty from start to publication of research.

The authors of nine articles called out the importance of better preparing undergraduates to engage in research and preparing them earlier in their academic programs. For example, Perlman and McCann (2005) argued for the importance of promoting undergraduate research experiences earlier in the undergraduate career (i.e., prior to junior year). Interviewees in Shanahan et al. (2017) also felt that earlier and more consistent undergraduate research experiences should be prioritized. van Vliet et al. (2013) felt this was true especially in counseling psychology wherein it would be critical to emphasize the importance of research in professional practice early and to foster more positive feelings about research.

Morales et al. (2016) put forth the importance of pre-training of students with regards to research content and skills. Hvenegaard et al. (2013) argued that enhancing communication and organization of directed studies courses would serve to enhance awareness and increase student preparedness. The authors also noted that faculty should boast the benefits of undergraduate research to potential student participants to encourage awareness. However, the authors also noted that they did not survey faculty members who chose not to supervise undergraduate researchers. Thus, the perceived challenges to offering undergraduate research experiences and implications outlined in this article may be lacking. Sens et al. (2017) also found it helpful for students to understand the value of undergraduate research experiences, including how these experiences can support their future career, which can be seen as a form of preparation for research experiences. To support preparation for, and rigor of, undergraduate research experiences, Brew and Mantai (2017) suggested coordinating efforts to offer progressively more holistic and challenging undergraduate research experiences throughout a students’ postsecondary programs.

Tucker et al. (2017) highlighted the importance of early exposure to undergraduate research readiness to prepare students for research experiences throughout their degree programs and, ultimately, for competitiveness when entering the workforce. The authors highlighted two new modules that were introduced into the first- and second-year curriculum to support research readiness. Making research more exciting and interesting to early career students was one strategy that was suggested. It is also important to help students articulate what research is and how they can benefit from engaging in research. The authors made the important point that “if students are not involved in research experiences early on in their studies it may hamper their desire and ability to conduct research effectively, their understanding and awareness of the benefits and relevance of research skills, and motivation to continue with research” (p. 207).
Mahatmya et al. (2017) highlighted the importance of developing students’ perceptions of preparedness as a key player in promoting participation in undergraduate research. This study outlined the need for college readiness programs to include research readiness in order to increase access for early-career students who, according to this study, were less likely to participate in undergraduate research but were more interested in undergraduate research than upper-division students.

3.4.2. Implications Related to Marketing and Highlighting Importance of Undergraduate Research for Students and Faculty

The authors of eight articles pointed to implications related to marketing and elevating awareness of the importance of undergraduate research. Jones and Davis (2014) highlighted the necessity of institutional support, such as the establishment of centralized offices for undergraduate research, as a sign of commitment to promoting and financially supporting a research culture for undergraduates. Wayment and Dickson (2008) also highlighted the importance of institutional affordances, like hosting a university-wide research conference for students to participate in, to promote a culture of undergraduate research that may encourage further participation. Interviewees in Shanahan et al. (2017) also mentioned the importance of shared perspectives of faculty and administrators regarding the importance of undergraduate research and that undergraduate researchers need more institutionally supported mentorship. Similarly, Schwartz (2012) pointed to the importance of promoting institutional and departmental culture of research.

Brew and Mantai (2017) highlighted institutional structures, policies, and procedures as the first place for enhancing the tradition of undergraduate research at a research institution and noted that having a department head supportive of undergraduate research is key when promoting a culture where undergraduate research is seen as normal. That is, a top-down approach to implementing undergraduate research programming and requirements was recommended, while recognizing that communication among colleagues is also critical. The authors recommended professional development opportunities for all levels of faculty, including instructors, where faculty can share ideas and learn about opportunities for fostering undergraduate research. They make the point that faculty should be somewhat assertive when highlighting the value of undergraduate research to colleagues. The authors also highlighted an undergraduate research newsletter, undergraduate research conferences, and an undergraduate research working group as helpful for sharing ideas, although they do not indicate who these tactics are most useful for. Finally, the authors suggested supporting structures like disciplinary and undergraduate research student societies that provide a space for students to share ideas and learn about opportunities for undergraduate research.

Wayment and Dickson (2008) outlined more targeted tactics to more effectively distribute knowledge of undergraduate research opportunities and to offer more obvious and less intimidating means to apply for these opportunities (e.g., via a website, department newsletter, bulletin board, a standard online application, and faculty announcements in class). In this paper, implementing changes to overcome identified barriers led to increases in the number of students and faculty participating in undergraduate research and nearly all students who participated in undergraduate research went on to graduate school. van Vliet et al. (2013) pointed out that emphasizing early on the importance of research in professional practice can happen through educating undergraduates about the benefits of undergraduate research and making these experiences more widely visible and available. Two ways to increase visibility in counseling psychology offered by the authors were to advertise more widely online and to build research connections across disciplines.

Hirst et al. (2014) highlighted the importance of advertising the potential benefits of undergraduate research partnership programs between four-year institutions and community colleges in order to encourage expanded use of this model. Based on their findings which pointed to the power of social and experiential motivators for encouraging student participation in undergraduate research (especially for early-career students), Mahatmya et al. (2017) highlighted the importance of advertising undergraduate research as an expe-
perience that is available to all students. Finally, Jones and Davis (2014) took a more national perspective in highlighting the importance of distributing success stories of undergraduate research via the Council for Undergraduate Research and other organizations to encourage institutions and faculty to offer more opportunities.

3.4.3. Implications Related to Clarifying Expectations around Undergraduate Research

The authors of four articles pointed to implications related to clarifying expectations around undergraduate research. For example, one implication highlighted in Sens et al. (2017) was the importance of clarifying expectations for faculty members mentoring undergraduate researchers and the role that clearer expectations could play in reducing faculty burnout. In the new undergraduate research model outlined by Sens et al., mentors were intentionally selected who were willing to commit to the program and had set aside time to do so. This new model outlined clear expectations of how much time faculty would spend and who could assist them. This contrasted to the old model wherein expectations were less clear, and faculty demonstrated various levels of involvement, which led to inconsistencies in mentoring commitments.

Another article pointed to the importance of clarifying expectations within CUREs. That is, one of the main implications related to access outlined in Hvenegaard et al. (2013) revolved around enhancing communication and organization for directed studies courses, including the importance of universities outlining clearer guidelines, standards, and goals for undergraduate research experiences by establishing assessment standards and disseminating information about these experiences with other students and faculty to encourage involvement.

Brew and Mantai (2017) noted that differing definitions of undergraduate research put forth by interviewees could make it difficult to clarify expectations related to these experiences. The authors pointed to the importance of helping faculty more broadly and accurately conceptualize what undergraduate research was and what it could be. They also put forth the implication that encouraging people at multiple levels (postdoctoral students, graduate students) to play a role in mentoring undergraduates would help faculty offer undergraduate research experiences. We assume this implication is directed toward faculty who may not realize mentoring an undergraduate researcher can be a team effort. Finally, Spell et al. (2014) pointed out that “conceptions of authentic research and barriers to its implementation likely vary from individual to individual and institution to institution” (p. 108). Thus, the authors highlighted the importance of evaluating how undergraduate research and barriers to accessing undergraduate research are perceived in a specific context before creating expectations for reform.

3.4.4. Implications Relating to Financial Strategies and Motivators for Faculty

The authors of six articles highlighted implications related to making undergraduate research offerings more cost-effective. While the authors did point out the importance of increasing funding for undergraduate research (including student stipends), van Vliet et al. (2013) suggested creating a system for students to receive course credit for research when funding was unavailable. Sens et al. (2017) highlighted the cost-effectiveness of an undergraduate research program that is cohort-based where students can share supplies. Morales et al. (2016) suggested encouraging faculty to use external funding opportunities, including those available from the National Science Foundation and National Institute of Health, to encourage mentoring of undergraduates from other institutions. Brew and Mantai (2017) highlighted the value of a coordinated system to support faculty who are applying for grants to support undergraduate research in order to increase the chances of securing funding for additional opportunities.

When referring to a research partnership program between four-year institutions and community colleges, Hirst et al. (2014) highlighted the need for additional faculty and student support, including expanded use of research space and resources at the four-year institutions in order to make these opportunities more widely available for
community college students and faculty. Schwartz (2012) pointed to the importance of partnerships with research universities and their faculty in order to increase opportunities for undergraduate research. In this article, the costs associated with mentoring students of color meant that faculty took on fewer students. The authors pointed out that faculty might be more willing to mentor additional undergraduates if the benefits outweighed the costs. Partnering with research labs that have more resources was offered by one interviewee as a more cost-effective solution to ease the strain on faculty.

The authors of eleven articles pointed to implications related to the importance of providing faculty with incentives for mentoring undergraduate researchers. Most generally, Perlman and McCann (2005) argued for the importance of more support and rewards for faculty who offer opportunities for undergraduate research. Hurtado et al. (2011) also pointed to the importance of rewarding faculty for mentoring students outside the classroom and allowing faculty to worry less about publishing and more about teaching and mentoring. Brew and Mantai (2017) highlighted the importance of better preparing and rewarding faculty to offer undergraduate research via departmental and institutional structures and processes, including additional funding to support undergraduate research. The authors mentioned that faculty would be more likely to offer opportunities for undergraduate research if the university provided financial or workload rewards, including rewards for faculty who publish with students, build opportunities for inquiry into their courses, or secure grants that support student engagement in undergraduate research. Schwartz (2012) simply suggested supporting faculty by providing them with stipends.

Jones and Davis (2014) spoke to the importance of understanding faculty perceptions with relation to mentoring in ensuring the success of undergraduate research programs. Specifically, the authors suggested gathering formative data on faculty perceptions of undergraduate research in order to ensure faculty needs are met. This is especially important because if faculty do not feel supported, undergraduate research experiences will not be offered. The authors called for increased institutional support of undergraduate research, including financial support, support for materials, and other rewards for offering undergraduate research.

Several articles pointed to incentives in the form of reduced teaching or workloads. For example, Wayment and Dickson (2008) mentioned the importance of targeted tactics aimed at faculty including offering incentives and reduced teaching loads via restructuring of course coverage/offerings. Kiemiesky (2005) echoed the point that reduced teaching loads could serve as a strategy for increasing faculty availability and motivation to offer and support undergraduate research. The importance of offering reduced teaching loads is also suggested by van Vliet et al. (2013). Shanahan et al. (2017) spoke more broadly to the importance of offering faculty workload credit (i.e., as opposed to just teaching credit) to support faculty engagement with undergraduate research. Schwartz (2012) also suggested supporting faculty via reduction of time constraints (teaching, service) so faculty can offer more opportunities for undergraduate research.

Conversely, Shanahan et al. (2017) suggested that faculty who implement CUREs do this as part of their regular teaching requirements and, thus, receive the workload credit they deserve for promoting opportunities for undergraduate research. Related to the importance of offering CUREs was a recommendation offered by Spell et al. (2014) that institutions should offer grants for researchers to partner with educators to work together to develop research-based curricula and providing more faculty with professional and curricular development resources.

Several articles more specifically called out the importance of recognition in annual performance reviews and promotion and tenure review. Shanahan et al. (2017) addressed the need for more promotion and tenure credits/time/compensation to support faculty participation in undergraduate research. van Vliet et al. (2013) also highlighted the importance of providing faculty with incentives for mentoring in the form of financial or other awards and recognition in annual performance reviews. Schwartz (2012) pointed
to the importance of revising promotion and tenure guidelines to reward undergraduate research mentoring.

In recognizing the importance of faculty motivators, especially for those without external grants and for those early in their careers, Morales et al. (2016) suggested providing supplies for research, faculty summer stipends, teaching credit, conference travel for faculty, and stipends for students doing undergraduate research at other institutions. However, the authors recognized these would be more and less motivating across points in career or discipline and that effective motivational and support strategies will differ across the faculty. Overall, the authors pointed out that, without incentives, fewer students would be able to engage in undergraduate research at other institutions. Finally, Schwartz (2012) highlighted the need to support faculty emotionally to prevent faculty burnout that may arise from challenging mentoring experiences.

3.4.5. Implications Relating to Broadening Undergraduate Research Participation of Students from Differing Demographics

Eleven articles discussed the importance of broadening participation in undergraduate research across demographics. Several specifically spoke to the importance of addressing assumptions about students with regards to research. For example, Wolkow et al. (2014) pointed to a need to address the assumption held by personnel at two-year institutions that underprepared students are an impediment to innovation in lab courses. Brew and Mantai (2017) also suggested the importance of considering students beyond the academically high-achieving minority for undergraduate research experiences. Similarly, Shanahan et al. (2017) interviewees felt that recruitment of students from historically underrepresented groups, involvement of non-honors students, and enhanced use of communication technologies which beget expanded participation through distance mentoring, must all be prioritized. In Shanahan et al., interviewee’s perspectives highlighted the importance of faculty who recognize the worth of students beyond “A” students as potentially sound researchers and the importance of strong mentoring relationships.

Morales et al. (2016) found that faculty who valued diversity were more willing to mentor students from other institutions, which speaks to the importance of educating faculty about the value of diversity in the academy. Morales et al. pointed to the importance of continuing to help faculty realize the potential benefits of mentoring undergraduate researchers towards advancing their own research agendas during the summer and the fact that supporting external summer undergraduate researchers could mean an investment in future graduate students.

Several other articles spoke to the importance of meeting the needs of students from diverse backgrounds as a way to broaden participation. For example, van Vliet et al. (2013) recognized that institutions need to do a significant amount of work to support students from diverse backgrounds. However, the only specific tactic put forth was to diversify the faculty. Schwartz (2012) also suggested that institutions should encourage faculty to be more sensitive and responsive to student needs, especially those of students of color, and pointed to the importance of mentoring young students of color. Access to undergraduate research can mean access to transformative experiences and mentors who are willing to help students of color navigate life challenges beyond just those related to research.

In other cases, authors highlighted implications relating to expanding participation in undergraduate research by leveraging these opportunities across institution types, especially within two-year institutions. In Shanahan et al. (2017), interviewees claimed more equitable access is the future of undergraduate research and is obtainable by extending the reach of undergraduate research experiences to a diversity of models, disciplines, and institution types. Wolkow et al. (2014) made the point that students at two-year institutions make up a large proportion of STEM students of color and those living in poverty in the U.S. If we want to engage as many students as possible from historically underrepresented populations in a high-impact practice like undergraduate research, Wolkow et al. (2014) argued that we must make these experiences maximally effective at two-year institutions. Hirst et al. (2014) also pointed out that community colleges enroll
a majority of undergraduates today so helping community college students overcome barriers to accessing undergraduate research would have a huge impact on engaging more students in high-impact practices. Spell et al. (2014) found the lowest levels of authentic research occurred in non-major courses, indicating we need to focus efforts on integrating research-based learning into two-year institutions and courses for students without majors.

Kierniesky (2005) extended this idea from the context of two-year institutions to small, liberal arts institutions by highlighting that psychology departments need more resources to support undergraduate research. The authors pointed out that “research activity can demand disproportionate resources at many smaller schools” (p. 85) and argued that more resources are needed in the smaller, less selective schools, in particular, where there is less apprenticeship-style undergraduate research compared to students exploring their own ideas (i.e., a more liberal education model of undergraduate research) and where faculty resources are even more limited.

van Vliet et al. (2013) highlighted the importance of increasing student opportunities for qualitative research as a way to broaden participation in counseling psychology. The authors recommended the creation of a faculty-mentored undergraduate research internship in counselling psychology as a way to create a structure to promote these experiences and suggested employing department-wide coordination of applications and matching.

Finally, while there were no direct implications related to undergraduate research or STEM, Pérez Huber (2010) offered a social justice argument for eliminating barriers to educational access and encourages further research on racist nativism and intersectionality in order to encourage more successful participation of undocumented, Chicana female students in postsecondary education.

4. Discussion

4.1. A Lack of Focus on Barriers for STEM Students of Color

In this article, we present a rigorous, systematic literature review that had the initial goal of examining the extent to which barriers to accessing undergraduate research are present for students of color in STEM programs across postsecondary institution types. We were surprised to find very few articles pertaining to our original research interest (i.e., Pérez Huber 2010; Schwartz 2012); this gap resulted in expanding our inclusion criteria to include articles exploring barriers to accessing undergraduate research, more generally. The 18 articles identified using these expanded inclusion criteria yielded an extensive list of barriers to accessing undergraduate research experiences across disciplines and demographics (outlined in research question #1, above), many of which were not obvious to us when starting this project. Most of these barriers, however, speak to all students and do not focus on issues of access specific to students of color or specific to those in STEM fields.

We find the overall lack of research exploring barriers to accessing undergraduate research experiences for STEM students of color concerning. We cannot state definitively whether this lack of research exists because these barriers do not manifest as barriers to undergraduate research or simply because this question has not yet been explored to a significant degree. Yet we suspect that, given the nature of the ten categories of barriers to success in STEM postsecondary contexts for students of color highlighted in the results section (see subheading, “Non-Structured Literature Review”), barriers may significantly influence students’ access to undergraduate research experiences.

For each of the ten categories of barriers to success in STEM that we identified in the non-structured literature review, we ask, could this barrier also manifest as a challenge in access to undergraduate research opportunities for STEM students of color (see Table 2)? For example, we found that racism, subtle racialized messaging, and social exclusion serve as barriers to success in STEM postsecondary contexts for some students of color. Could managing instances of racism, discrimination, tokenism, stigmatization, exclusion, prejudice, and other race-based phenomena overburden a student and discourage them from seeking out opportunities for undergraduate research? We also found that
STEM fields claiming to be objective or neutral in nature serves as a barrier to success in STEM postsecondary contexts for some students of color. The gendered, raced, and classed history of STEM fields means that barriers to access may exist in the forms of conscious or unconscious biases of professors and deeply rooted institutional and systemic forms of oppression. Could the lack of discussions around class, race, gender, ethnicity, sexual orientation, or immigration status in STEM, or barriers related to the intersection of these identities, distance some students of color from STEM fields and make them less likely to seek out research experiences?

Table 2. Ten categories of barriers to success for STEM undergraduate students of color resulting from the preliminary non-structured literature review and questions we pose to encourage researchers to explore whether these barriers manifest as challenges in access to undergraduate research opportunities for STEM students of color.

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<thead>
<tr>
<th>Category of Barrier from Non-Structured Literature Review</th>
<th>Questions to Explore Implications for Access to Undergraduate Research</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. A lack of representation at all levels within the college/university, the absence of culturally relevant role models and peers, and being considered to act as a representative of one’s group</td>
<td>Could STEM students of color be discouraged from entering undergraduate research experiences if their identities are not represented? Could a student interpret this lack of representation to mean the research environment is an unwelcoming place for people of color?</td>
</tr>
<tr>
<td>2. Difficulty bridging cultural expectations and norms with expectations and norms in academia, handling conflicting identities, and managing excessive peer/family support or pressure while navigating STEM postsecondary contexts</td>
<td>Could students of color be discouraged from participating in undergraduate research experiences if family obligations and expectations require that students spend more time at home, away from campus?</td>
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<tr>
<td>3. Exposure to stereotypes, pressure and doubt from self and others, a lack of identity and belonging, and feelings of inadequacy and conspicuousness, in addition to the physical side effects of these psychosocial barriers</td>
<td>Could feelings of isolation, alienation, and non-assimilation; a lack of belonging and identity; imposter syndrome; a decline in self-concept; low confidence and self-efficacy; self-doubt; stereotype threat; and stress and anxiety associated with perceptions of difference (as well as the additive effects of these psychosocial phenomenon) overburden some students and contribute to a decreased likelihood of seeking out an undergraduate research experience?</td>
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<tr>
<td>4. A lack of access to high-quality academic preparation and academic resources prior to college</td>
<td>Could attending under-resourced schools prior to college mean that some students of color are not given the tools to earn top grades in rigorous STEM college courses? As many undergraduate research opportunities are often distributed based on performance in classes (as indicated by Shanahan et al. 2017), could attending under-resourced schools translate into a barrier to accessing opportunities for undergraduate research?</td>
</tr>
<tr>
<td>5. High financial need and a need to work while in school</td>
<td>Does the fact that many undergraduate research opportunities are unpaid make them less accessible for students who are more likely to work to fund their college education and/or help support themselves and their families? In addition, could students who are working to support themselves miss opportunities to network with professors (e.g., office hours, review sessions), leading to undergraduate research opportunities?</td>
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<tr>
<td>6. Institutional issues including an unwelcoming campus climate, unsupportive/unempathetic faculty members, and the promotion of competition in some STEM courses</td>
<td>Could perceptions of an unwelcoming campus climate cause some students of color to avoid calling attention to themselves in and outside of class? Could this behavior be misinterpreted by faculty as a lack of interest in the material, preventing students from developing important connections with professors that could lead to undergraduate research experiences? Could the promotion of competition among peers in STEM classes and the perception that professors are arrogant, intimidating, unapproachable, and uncaring may make some students of color feel less comfortable with the prospect of seeking out undergraduate research experiences?</td>
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<tr>
<td>7. A lack of access to information about college life and STEM culture or a lack of access to important forms of social/cultural capital</td>
<td>Could limited awareness of the benefits of undergraduate research, how to navigate the research enterprise, educational policies, procedures, and support programs make it more difficult to find one’s way into a research experience?</td>
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Table 2. Cont.

<table>
<thead>
<tr>
<th>Category of Barrier from Non-Structured Literature Review</th>
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<tr>
<td>8. STEM fields claiming to be objective or neutral in nature; the gendered, raced, and classed history of STEM fields means that barriers to access may exist in the forms of conscious or unconscious biases of professors and deeply rooted institutional and systemic forms of oppression.</td>
<td>Could the lack of discussions around class, race, gender, ethnicity, sexual orientation, or immigration status in STEM, or barriers related to the intersection of these identities, distance some students of color from STEM fields and make them less likely to seek out research experiences?</td>
</tr>
<tr>
<td>9. Growing disinterest in STEM or greater interest in another field</td>
<td>Could a loss of interest in STEM be driven by the cumulative effects of other barriers highlighted in our review? Could this loss of interest mean that some students of color feel less inclined to further immerse themselves in their disciplines by seeking out undergraduate research opportunities?</td>
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<tr>
<td>10. Racism, subtle racialized messaging, and social exclusion</td>
<td>Could managing instances of racism, discrimination, tokenism, stigmatization, exclusion, prejudice, and other race-based phenomena overburden a student and discourage them from seeking out opportunities for undergraduate research?</td>
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This review explored articles about student barriers to participating in undergraduate research experiences up through 2017. While there was a lack of focus on barriers for STEM students of color identified in this review, we are encouraged to see more recent work exploring challenges that students of color may face when accessing opportunities for undergraduate research. For example, several scholars have recently begun to investigate barriers to fieldwork, an integral aspect of many undergraduate research experiences, and how these barriers disproportionately impact, and serve to exclude, students of color (e.g., Giles et al. 2020; Morales et al. 2020). In another recent study, scholars found that 60% of respondents who “strongly agreed” that research is only for future scientists were Latinx, revealing a need to promote the importance of the undergraduate research experience as an inclusive tool for learning, growth, and belonging for all students, regardless of career trajectory (Amaya et al. 2018). These are promising steps forward as we work toward a more holistic picture of barriers to accessing undergraduate research for STEM students of color.

4.2. A Focus on Surface-Level Strategies

The authors of the articles we reviewed highlighted a wide range of strategies for overcoming barriers to undergraduate research experiences for students, which may, in fact, be of benefit for other stakeholders as well, including faculty members, academic departments, and the institution. These included curricular strategies (e.g., offering CUREs and promoting better/earlier student preparation), strategies related to marketing (highlighting the importance of undergraduate research), strategies regarding clarifying expectations around undergraduate research, and financial and other motivational strategies for faculty participation (e.g., making undergraduate research more cost effective and providing faculty incentives).

Of the 18 articles we reviewed, 11 mentioned implications related to the importance of broadening participation in undergraduate research. Yet we found these offerings to be lacking in detail, overly concise, and not of a critical nature. For example, there were no articles that explicated the importance of helping students of color navigate feelings of racial isolation or institutional and systemic forms of racism that might stand in the way of opportunities for undergraduate research. Instead, most authors engaged in conversations about broadening participation in “nice” ways (as described by Castagno 2014, p. 1), for example, by simply suggesting the importance of considering students for research experiences beyond the privileged minority (e.g., Brew and Mantai 2017) without critically exploring ways to overcome the inequities that may lead to differential access.
4.3. Limited Use of Theoretical/Analytical Frameworks

Given the relevance of the 18 articles we identified relative to our broader research interests, and in the interest of future research, we were concerned to find a fairly limited use of theoretical/analytical frameworks across only five articles with only two of these employing critical lenses. We contend that employing critical lenses can illuminate potential race-related barriers that may perpetuate differential access to undergraduate research, that may often go unnoticed through the use of theoretical frameworks that reinforce dominant narratives about the majority, as well as insight into remedies. As an illustration, Tucker et al. (2017) claim to contribute to the theory of research preparedness by reporting that student barriers to accessing undergraduate research include not being interested in the work, low confidence to do research, needing more support for preparation, and a lack of research ability. The use of the theory of research preparedness in this article presents two major problems that may be representative of other dominant-narrative frameworks: (1) it may promote deficit-thinking by allowing the placing of “blame” on students for their lack of interest and ability, and (2) it fails to address how individuals may be differentially affected by structures, practices, and systems that influence participation. In this way, the experiences of students from historically underrepresented groups are not specifically considered or attended to, potentially leaving many, or more nuanced, phenomena about access unexplored. We found the use of theories that reinforce dominant narratives, like that in Tucker et al., to be fairly typical across the articles reviewed. By using theories that primarily represent dominant narratives, or by failing to employ a theoretical lens to critically explore relevant realities (as in the majority of studies exploring this topic, e.g., Hirst et al. 2014; Wayment and Dickson 2008), researchers may fail to illuminate potential race, class, and gender-based issues that may impact students’ access to research experiences, and, in turn, are unable to represent the experiences of students of color and allow insight for how to attend to these (Solórzano and Yosso 2016; Zamudio et al. 2011).

We assert that by employing theoretical frameworks with critical lenses with respect to explicit questions and appropriate data collection, we might uncover institutional systems and practices that may promote race-based inequalities. Only then can we begin to provide a more complete systems-perspective of relevant societal, cultural, and historical factors impacting undergraduate research experiences, including the voices of those historically underrepresented and silenced in postsecondary STEM. Critical Race Theory is one framework that could be employed more regularly to address issues of access to undergraduate research, as it brings a critical consciousness to the ways in which institutional and systemic racism may affect issues of inclusion in higher education (Solórzano and Yosso 2002). Other frameworks not specifically considered a critical theory, but with a systems-theory perspective such as cultural-historical activity theory, may have the potential to encourage researchers to consider and understand multiple perspectives and the many interacting factors influencing them.

5. Implications

From our research, we see the following as potential actions and commitments for various stakeholders.

5.1. Institutions and Administrators

Increase the amount of resources allocated for undergraduate research experiences. We recommend that institutions predominantly focus on allocating resources for faculty incentives, like summer pay and course buyout, to address challenges related to a lack of faculty incentives. In addition, we recommend that institutions ensure students receive financial compensation for hours spent conducting research in order to overcome the financial constraints that prevent some students from participating in undergraduate research.

Build centralized institutional or college offices with personnel devoted to helping students learn about and prepare for undergraduate research experiences. We assert that support personnel and centralized programming may elevate undergraduate research activities to be more
high-profile as well as easier for students to access. According to Jones and Davis (2014), centralized offices for undergraduate research "are more than symbolic gestures and mailing addresses for [Council on Undergraduate Research] membership materials. Activities sponsored by these offices provide direct training for faculty and students, help connect students interested in undergraduate research with (perhaps interdisciplinary) faculty members, and assist faculty with identifying external funding sources for undergraduate research, among other key tasks” (p. 40). A centralized office could host a campus-wide display of student research or coordinate awards of excellence in mentoring and student research. In addition, having a set of centralized resources may alleviate pressures felt by individual faculty and advisors who are tasked with helping students navigate the process of engaging in undergraduate research alongside various other responsibilities. A centralized unit may additionally minimize duplication of undergraduate research-related resources and spending across campus.

Devote support for offering of CUREs across campus. Early-program CURE experiences may have a greater influence on a student’s career path than research experiences that take place late in a student’s undergraduate career (Auchincloss et al. 2014) and may reduce the stresses placed on students when trying to balance coursework with an apprenticeship-style research experience (Rowland et al. 2012). Bangera and Brownell (2014) argue that requiring CUREs in introductory-level courses represents a more equitable way to ensure all students have the opportunity to engage in a research experience, which helps guarantee that all students have the same skills that could be transferred to other research experiences, internships, or graduate school. Institutions should provide faculty with professional development incentives to redesign courses with a research component. In doing so, institutions should support mechanisms that connect those with experience implementing CUREs with those desiring help with the process (e.g., possibly through an institution’s center for teaching and learning).

Revise promotion and tenure guidelines, so that faculty recognition is given for mentoring undergraduate researchers from diverse backgrounds, and learn from those institutions that already have. The promotion and tenure process serves as a way for the institution to communicate what type of work is valued (Paul 2011). Yet few institutions actively and robustly support undergraduate research activity in promotion and tenure processes. While faculty advancement of undergraduate research inherently may be conceptualized, and rewarded, across all three areas in which promotion and tenure are most traditionally evaluated—teaching, research, and service—we caution that doing so may not afford this faculty contribution. Regardless, we recommend that institutions make explicit the ways in which undergraduate research mentoring can be represented and assessed within the promotion and tenure processes, perhaps borrowing from others. For example, within Weber State University’s College of Science, the dossier requires an articulation of how many undergraduate student projects were mentored, how many publications resulted from this work, and whether the undergraduate research experiences influenced the student’s acceptance into graduate school (Vaughan 2011).

Devise alternate ways of evaluating the impact of time spent mentoring undergraduate research. Schultheis et al. (2011) make the point that mentoring of undergraduate research should be formally evaluated, similar to the way courses are evaluated, so that potential evidence of the effectiveness of this work can be clearly articulated in the promotion and tenure process. Institutions can encourage departments and colleges to allow apprenticeship-style undergraduate research experiences to count as independent study courses or replace upper division elective credits. This could address multiple concerns by (1) allowing students to continue advancing in their coursework while engaging in research with faculty, (2) reducing barriers for students who cannot afford to volunteer their time to engage in research without financial incentive, and (3) allowing faculty to demonstrate that time spent mentoring more clearly aligns with their teaching effort, as assessed in the promotion and tenure process.
Schultheis et al. (2011) also put forth the idea that faculty peer evaluation could be an alternate way to assess the effectiveness of a faculty member’s mentoring. Similar to the ways in which institutions use peer evaluations of teaching in the promotion and tenure process, peer faculty could attend group research meetings and observe several collaborative research sessions before composing a written evaluation of the mentoring to put forth for review. This peer observer might comment on the ways in which the faculty mentor is supporting the undergraduate’s learning and advancement in the field. We take these suggestions one step further and recommend that any student-based or peer faculty-based evaluations also comment on the ways in which the faculty mentor is promoting diversity, equity, and inclusion as a mentor. Ultimately, we contend that making values regarding promotion of equity and inclusion more explicit to faculty throughout their affiliations and promotions at institutions will encourage faculty to expand their perceptions about who should be allowed and encouraged to participate in undergraduate research.

Make the importance of undergraduate research activity explicit in faculty recruitment, hiring, and socialization processes. Hernandez Jarvis et al. (2011) recommend that institutions include wording in job announcements about the expectation that new faculty will develop research agendas that involve undergraduates. The authors also suggest that institutions make the importance of involving undergraduates in research explicit during the hiring process by having candidates meet with undergraduates interested in research and ensuring that candidates are exposed to campus marketing materials advertising research programs, showcases, and students’ published work.

Use data-driven approaches (quantitative and qualitative) to assess the impact of the changes they choose to implement on students, faculty, and the institution. We recognize that shifts in institutional processes and procedures take time. However, steps can be made toward building a reputation for research excellence and inclusion by implementing the strategies outlined in this section. Demonstrating the differential impact of particular policies and programs on students will help the institution see the relative efficacy of effort, and where more effort needs to be expended. These data can also help convey the worth to relevant stakeholders (e.g., other administrators, faculty, parents, funders, policy makers) of encouraging as many students as possible to engage in undergraduate research toward promoting student retention and diversity goals, as well as their (and faculty members’) success.

5.2. Individual Faculty Members and Their Colleges, Departments, and Societies

Make a concerted effort to help students learn about opportunities for undergraduate research and apply for these experiences. Our review revealed that both a lack of student awareness of the benefits of undergraduate research, as well as students being intimidated by faculty, both served as barriers to accessing opportunities for undergraduate research (Tucker et al. 2017; Wayment and Dickson 2008). Thus, we recommend that faculty employ empathy when interacting with students, including having patience and being a good listener, in order to reduce the amount of intimidation that students feel when interacting with faculty. In order to promote these changes in behavior, we call on colleges and departments to help faculty understand that not all students feel comfortable engaging with faculty and that some students from historically underrepresented groups may not see themselves represented as major knowledge producers in the professoriate (as noted by van Vliet et al. 2013), which could affect their sense of belonging and inclination to seek out research partnerships with faculty. To promote this awareness and to help build empathy for undergraduates, we recommend that colleges and departments invite esteemed colleagues with cultural capital to give guest seminars or keynote addresses at society meetings that outline the role faculty play in supporting and developing the next generation of diverse professionals in their respective fields.

Expand opportunities for undergraduate research experiences, via coursework and student funding. Student time and compensation prevent student participation in undergraduate research (e.g., Hirst et al. 2014). Some students cannot afford to spend extra time engaging in volunteer or poorly paid research experiences, meaning these experiences are often reserved
for those who are more financially secure. Offering opportunities for undergraduate research as part of a student’s regular curriculum allows a student to engage in the research experience without spending extra time outside of required coursework (Bangera and Brownell 2014). While we feel that agency lies with the faculty to help alleviate this contradiction, this will become easier for faculty if institutions support faculty efforts to develop CUREs, as outlined above. Programs may also wish to leverage Federal Work-Study to fund student-faculty research partnerships. This strategy is low-cost for faculty and offers students a more scholarly alternative for receiving a Federal Work-Study financial award than many food service or desk jobs (Nazaire and Usher 2015). If neither of these options are available, we recommend that the faculty member explore with the student the option of having their unpaid research hours replace upper division electives. This way, the student may still make progress toward their degree requirements while engaging in research. As a final note, faculty should also remember to always write in funds to hire undergraduate researchers when negotiating start-ups, applying for grants, and during any other opportunity to secure support for their research, notably in high pressure situations where faculty may not remember to consider the promise of working with/supporting undergraduate researchers.

Academic colleges, departments, and professional discipline-specific societies must help faculty shift their perceptions of which students should be allowed to engage in undergraduate research. This review revealed that faculty perceptions of student capacity and competency sometimes prevented students from accessing opportunities for undergraduate research (Brew and Mantai 2017; Jones and Davis 2014). Colleges, departments, and professional societies must foster a shift in faculty members’ deep-seated practices and perceptions toward considering greater equity and inclusion in undergraduate research. Faculty can be motivated to participate in social justice workshops, trainings, or conversations that help them understand important realities like students’ potential intersectionality, the difference between equality and equity, and the range and extent of personal challenges that students may experience, which may prevent the achievement of top grades and prior research experience. These trainings may help faculty think more critically about the reasons why some students do not satisfy their more traditional metrics of merit (i.e., top grades and previous research experience). Do some students lack access to supportive mentors and encouragement to prepare for undergraduate research? Did institutional and/or societal barriers negatively impact a student’s academic performance starting in the K-12 system? It is possible that this shift in perceptions of who should be involved in undergraduate research will occur when faculty become aware of the importance of diversifying the institution and diversifying their respective disciplines through these trainings and conversations.

We recognize that faculty have little time to engage in activities outside of those that contribute to research and teaching. Thus, we recommend that college, departments, and disciplinary societies rely on research-supported tactics for encouraging faculty to attend meaningful professional development sessions. These could include offering extrinsic motivators, including policies as well as those felt more “positively” by educators such as funding, food, and encouragement of trusted STEM colleagues in their professional networks (Bouwma-Gearhart and Adumat 2011; Bouwma-Gearhart 2010, 2012; Bouwma-Gearhart et al. 2016; Fisher et al. 2019). Other strategies could include hosting these events during social hours where lunch and/or beverages are provided, having department heads or deans deliver strong messaging that participation in expected, or by hosting such professional development sessions during faculty meetings where attendance is already required or likely per faculty members’ other interests (Bouwma-Gearhart et al. 2018, 2019).

Once faculty become aware of the importance of supporting equity and inclusion in undergraduate research, we recommend that they rely, instead, on less traditional metrics of merit when selecting undergraduate researchers, including a demonstrable passion for research, curiosity, and dedication to one’s studies. That being said, we recognize that the pressures on faculty to excel in research and teaching will remain. Thus, we also recommend that faculty call on graduate students and more experienced undergraduates
to play a role in mentoring new students who are still developing the skills required to work more independently in a research environment (Feldman et al. 2013; Pierszalowski et al. 2018; Reddick et al. 2012).

We realize that faculty will be (understandably) hesitant to accept an undergraduate researcher with no relevant skills or experience. However, we encourage faculty to recognize that expecting that students come in with graduate-level proficiency in research will put many students at a real disadvantage and promote the use of institutional strategies to help them do this. We assert that faculty must move past a deficit perspective of student performance and preparation towards a view of undergraduate research experience as an educational training opportunity for students to develop and hone the skills and tools necessary to excel as researchers (Hunter et al. 2007).

5.3. Educational Researchers

We found very few articles with empirical evidence outlining barriers to accessing undergraduate research for students of color in STEM, as per our original interest. Thus, we engaged in a methodology that applied categories of barriers for students of color that we identified in the preliminary nonstructured literature review to a structured literature review around experiences for all students in STEM. Again, we may have not identified all barriers to accessing research for STEM students and recommend future research allowing for identification of additional barriers for all STEM students. This review has certainly illuminated the fact that more research needs to be done to determine whether there are barriers to accessing undergraduate research experiences for STEM students of color, beyond the limited evidence found in this review. The gaps in the literature that we highlighted, as well as the questions we pose in Table 2, may serve as a springboard for future research that, in turn, may help educators and administrators recognize a need for, and means to, promote more equitable access to undergraduate research experiences for students of color in STEM fields.

We recommend that researchers pay particularly close attention to the questions that emphasize potential structural and institutional barriers, as these tend to represent the more complex, deep-seated challenges that deserve dedicated attention. Specifically, we recommend that educational researchers employ a critical lens to advance research agendas around (1) the ways in which the gendered, raced, and classed history of STEM fields intersect with a student’s tendency to engage in research, (2) how perceptions of campus climate influence one’s likelihood of seeking out an undergraduate research experience, and (3) the ways in which institutional practices, policies, and procedures may differentially influence students of color in ways that inhibit access to undergraduate research.

6. Conclusions

This article represents a rigorous, systematic literature review with the original goal of examining the extent to which barriers to accessing undergraduate research for STEM students of color across postsecondary institution types have been addressed with peer-reviewed research. However, while this investigation revealed interesting findings with regard to student, faculty, and institutional barriers to accessing undergraduate research experiences in general, we found a lack of research exploring barriers to accessing undergraduate research experiences for students of color, specifically. By leaving this topic unexplored, we contend that scholars fail to consider potential challenges that students of color may face that preclude opportunities for transformative research experiences.

This literature review goes beyond the level of summarizing what is known in the field. Instead, it serves as a meta-synthesis that draws broad conclusions from prior work, offers a critical look at the rigor of research that has been conducted, and situates findings within a theoretical framework. This analytical review makes another important contribution to the field by providing a summary that looks broadly across barriers to success and persistence in postsecondary STEM programs for students of color. This summary ultimately prompted us to pose questions regarding whether these barriers to success and persistence in STEM
also get in the way of STEM students’ of color access to undergraduate research experiences. In doing so, this allowed us to identify potential gaps in what is known about access to undergraduate research and recommend areas that implicate future research.

From here, we noted various strategies for improvements, to ensure the prevalence and success of undergraduate research experiences, that can result in gains for students, faculty, and relevant postsecondary organizations. It is likely that those who have been privileged enough to receive sufficient preparation to engage and excel in undergraduate research experiences will have the confidence and encouragement to advocate for additional research-related experiences. During a time when our nation struggles to close opportunity gaps for students from historically underrepresented groups (National Science Foundation 2018), we feel it is paramount that faculty begin to recognize the undergraduate research experience as a tool to promote equity and inclusion in their disciplines, at the institution, and in society at large. By providing research experiences for students who might normally face barriers to engaging in them, we can help to ensure a more diverse group of individuals has access to the many personal and professional gains shown to result from participation in undergraduate research. This, in turn, will benefit us all by helping to promote social justice and by cultivating the next generation of high-quality professionals that enter the U.S. workforce.

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Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

The thirty-eight articles included in the preliminary, non-structured literature review which yielded ten emergent categories of barriers to success for students of color in relation to STEM at the postsecondary level.


**Appendix B**

Search terms used to identify articles addressing barriers to undergraduate research in the structured literature review. The “+” indicates search terms that were added in addition to “undergraduate research”, “barrier”, and “students of color. Note that some of the papers that met inclusion criteria were identified in multiple searches.
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Appendix C

Ten categories of barriers to success for STEM undergraduate students of color resulting from the preliminary non-structured literature review.

<table>
<thead>
<tr>
<th>Broad Category</th>
<th>Subcategory</th>
<th>Examples</th>
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| Lack of representation/lack of role models | Lack of representation at all levels within the college/university | 1. Lack of ethnic/cultural representation in school, faculty, class, and the curriculum, and the associated discouragement of this isolation  
2. Overrepresentation in athletics  
3. Not representing a critical mass or a large enough group to have a social and academic peer group with similar backgrounds |
|                                | Absence of culturally relevant role models and peers                        | 1. An absence of culturally-relevant role models and mentors in and outside of STEM  
2. Challenges with finding other students with similar backgrounds and academic  
   experiences in their majors |
|                                | Being considered to act as representatives of group                         | 1. Being considered to speak and act as a representative of a respective group while majority peers speak and act as individuals |
|                                | Difficulty bridging cultural expectations and norms with expectations and norms in academia | 1. Cultural dissonance/incongruence  
2. Embracing values that are not emphasized in STEM fields (e.g., activism, community  
   engagement) means less time focused on success in STEM  
3. Family obligations mean less time on campus |
| Family and cultural barriers   | Conflicting identities                                                      | 1. Being ostracized by peers when one embraces values of dominant society, concern about racial betrayal  
2. Having to deny culture to be accepted by peers  
3. Passing as white to overcome negative perceptions of race/ethnicity  
4. Separate social and academic lives can mean some students of color are deprived of  
   benefits of sharing important information and group studying with other students |
|                                | Absence of peer/family support or excessive peer/family pressure            | 1. Families may question long-term goals of becoming a scientist  
2. Fear of disappointing the family  
3. Pressure to bring something useful back to the community  
4. Pressure to contribute to the family financially, maintain the family structure, uphold  
   family commitments, provide childcare, and uphold family ideals  
5. Weakening ties to family and home  
6. Peers unsupportive of academic success |
|                                | Exposure to stereotypes                                                     | 1. Stereotype threat or stress associated with the perception that academic performance is representative of a group  
2. Concerns about deviating from traditional stereotypes  
3. Being vulnerable to academic/social stereotypes of racial/ethnic/gender identities  
   (including the perception of only being qualified for college because of affirmative action) |
|                                | Additive psychosocial effects                                               | 1. Additive psychosocial effects of belonging to more than one marginalized group for women of color  
2. Layers of marginalization |
| Psychosocial barriers          | Physical side effects of psychosocial barriers                             | 1. Time devoted to combating psychosocial barriers through social performance strategies means less time pursuing success in STEM  
2. Anxiety leading to increased blood pressure and reduced working memory capacity  
3. Psychological stress and social tensions  
4. Stereotype threat leading to non-participation, anxiety, and underperformance |
|                                | Pressure and doubt from self and others                                    | 1. Having doubts associated with tokenism and environmental discomfort  
2. Skepticism from others and oneself about qualifications and abilities to succeed  
3. Anxiety that behavior might conform to negative stereotypes  
4. Pressure to prove intellectual ability despite prior academic achievements  
   (motivational and performance vulnerability)  
5. Fear of failure and having to overcome negative cognitive side effects of  
   academic setbacks  
6. Interpretation of one’s difficulties as a lack of ability  
7. Imposter syndrome |
|                                | Feeling conspicuous                                                         | 1. Gender/race/ethnicity is more salient to oneself  
2. Avoiding calling attention to oneself |
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<th>Broad Category</th>
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<th>Examples</th>
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| Lack of belonging                    |                                      | 1. Feelings of social difference, non-assimilation, discomfort, lack of belonging, and academic/cultural/social isolation in STEM courses, laboratories, and at the university  
2. Feeling invisible, overlooked, alienated, neglected, unwelcomed, unsupported, and discriminated against (sometimes by meaningful others within science) |
| Lack of identity                     |                                      | 1. An absence of social identity due to skepticism about intellect/aptitude for scientific research and lack of community understanding/support  
2. Having to employ fragmentation and/or passing  
3. A sense that competence and belonging are questioned because one’s body does not align with the prevalent image of an “ordinary” white, male scientist |
| Feeling inadequate                   |                                      | 1. Displays of self-doubt  
2. Low confidence/self-efficacy, including career decision-making self-efficacy  
3. Susceptibility to intimidation |
| Barriers associated with academic preparation |                                      |                                                                 1. Less access to advanced math and science courses in high school  
2. College gatekeeper courses are challenging to navigate with substandard high school preparation |
| Lack of resources prior to college   |                                      | 1. Fewer technical toys before college  
2. Attended schools with fewer resources (funding, facilities, positive role models, career counselors, quality teachers, high-quality curricula, computer and internet access)  
3. Larger class and school sizes in high school |
| High financial need                  |                                      | 1. Family pressure and stress regarding financing college  
2. The lack of a financial “safety net” for those who change their major  
3. Some likely to face unmet need, inadequate financial aid  
4. A diminishing number of need-based funding for students |
| Need to work                         |                                      | 1. Many work part-time to pay for school  
2. Having to skip educational opportunities to work (e.g., missing professor’s office hours) |
| Issues in the classroom/curriculum   |                                      | 1. Professors’ practice of asking questions during a lecture disadvantage those who avoid attracting attention in class  
2. The promotion of competition (fostering a “survival of the fittest” and “weed out” mentality) disadvantages those facing other barriers  
3. Faculty are resistant to discuss gender and race issues in classrooms  
4. Lived experiences of students are not integrated into the process of learning science (difficult to identify with course content)  
5. Lack of community in introductory science courses |
| Institutional barriers               |                                      | 1. Misalignment of campus climate and culture  
2. Some experience an unwelcoming, inhospitable, unsupportive, chilly, racial, hostile, campus and STEM climate  
3. Institutional insensitivity to unique needs and experiences of students of color  
4. Some face institutional discriminatory practices and policies  
5. Vulnerability in institutional commitment to diversity due to tenure of university leadership |
| Campus climate                       |                                      | 1. Some experience exclusion from informal interactions with faculty  
2. Inability of professors to make science accessible and relevant to societal problems  
3. Faculty rushed, arrogant, negative, inaccessible, intimidating, unapproachable, discouraging, unsupportive, and perceived to be uncaring  
4. Faculty not focused on building relationship in the classroom |
| Lack of information                  |                                      | 1. Some have inadequate knowledge about college life, graduate school, career paths, and STEM culture  
2. Some have limited awareness of educational policies, procedures, and support programs |
| Inadequate human and cultural support|                                      | 1. Some have difficulty obtaining adequate advising, counseling, tutoring, education/career planning, and monitoring  
2. Some lack family guidance and support when navigating college and STEM fields  
3. Some have difficulty navigating social hierarchies |
<table>
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<tr>
<th>Broad Category</th>
<th>Subcategory</th>
<th>Examples</th>
</tr>
</thead>
</table>
| Historical barriers/barriers historically associated with STEM fields | STEM cultural barriers | 1. The gendered, raced, and classed history of STEM fields  
2. An incompatible media image of an engineer/scientist  
3. The issue of responding to standards not traditionally intended for minority students  
4. The sociocultural boundaries associated with membership in the scientific community  
5. The notion that STEM is traditionally for the entitled  
6. Historical laws prohibiting the entry of minorities into education and employment  
7. A lack of (or token) acknowledgement of minority scientist accomplishments  
8. A lack of focus on individuality and context |
| | STEM as neutral | 1. The false notion that science is purely meritocratic and is neutral to race, ethnicity, gender  
2. An insensitivity to the unique needs, experiences, and priorities of students underrepresented in STEM  
3. Having to conform to the behavioral norms and appearance of white, male science culture  
4. There is no approved place for discussion of class, race, ethnicity, gender, sexual orientation, or immigration status |
| Barriers associated with a loss of interest | Growing disinterest in STEM | 1. Rejection of lifestyle associated with STEM  
2. A belief that STEM is too technical or difficult to apply to practical, real-world issues  
3. An association of STEM with words that have negative connotations, generating negative attitudes toward STEM  
4. A mismatch between the student’s interests and performance |
| Greater interest in another discipline | 1. A belief that non-STEM majors will provide greater intrinsic interest |
| Barriers associated with racism | Racism | 1. Dealing with racism, discrimination, tokenism, racial antagonism, stereotypes, spotlighting, stigmatization, and prejudice |

References


Bangera, Gita, and Sara E. Brownell. 2014. Course-based undergraduate research experiences can make scientific research more inclusive. *CBE Life Sciences Education* 13: 602–6. [CrossRef]


Bouwma-Gearhart, Jana, Adam Lenz, and John Ivanovitch. 2019. The interplay of postsecondary science educators’ problems of practice and competencies: Informing better intervention designs. *Journal of Biological Education* 53: 365–77. [CrossRef]


Bouwma-Gearhart, Jana, John D. Ivanovitch, Ellen M. Aster, and Andrew M. Bouwma. 2018. Exploring postsecondary biology educators’ planning for teaching to advance meaningful education improvement initiatives. *CBE—Life Sciences Education* 17: ar37. [CrossRef]


Feldman, Allan, Kent A. Divoll, and Allyson Rogan-Klyve. 2013. Becoming researchers: The participation of undergraduate and graduate students in scientific research groups. *Science Education* 97: 218–43. [CrossRef]


Hirst, Rachel, Gilles Bolduc, Louis Liotta, and Becky W. L. Packard. 2014. Cultivating the STEM Transfer pathway and capacity for research: A partnership between a community college and a 4-year college. *Journal of College Science Teaching* 43: 12–17. [CrossRef]


Hunter, Anne, Sandra L. Laursen, and Elaine Seymour. 2007. Becoming a scientist: The role of undergraduate research in students’ cognitive, personal, and professional development. *Science Education* 91: 36–74. [CrossRef]


Lopatto, David. 2007. Undergraduate research experiences support science career decisions and active learning. *CBE—Life Sciences Education* 6: 297–306. [CrossRef]


Morales, Danielle X., Sara E. Grineski, and Timothy W. Collins. 2016. Influences on Faculty Willingness to Mentor Undergraduate Students from Another University as Part of an Interinstitutional Research Training Program. *CBE Life Sciences Education* 15: ar35. [CrossRef] [PubMed]


Moran, Patricia. 2011. Bridging the gap between research and practice in counselling and psychotherapy training: Learning from trainees. *Counselling and Psychotherapy Research* 11: 171–78. [CrossRef]


Perlman, Baron, and Lee I. McCann. 2005. Undergraduate research experiences in psychology: A national study of courses and curricula. Teaching of Psychology 32: 5–14. [CrossRef]


Rowland, Susan L., Gwen A. Lawrie, James B. Y. H. Behrendorff, and Elizabeth M. J. Gillam. 2012. Is the undergraduate research experience (URE) always best?: The power of choice in a bifurcated practical stream for a large introductory biochemistry class. Biochemistry and Molecular Biology Education 40: 46–62. [CrossRef]

Russell, Susan H., Mary P. Hancock, and James McCullough. 2007. Benefits of undergraduate research experiences. Science 316: 548–49. [CrossRef]


Schwartz, Joni. 2012. Faculty as undergraduate research mentors for students of color: Taking into account the costs. Science Education 96: 527–42. [CrossRef]


Shanahan, Jenny, Helen Walkington, Elizabeth Ackley, Eric Hall, and Kearsley Stewart. 2017. Award-winning mentors see democratization as the future of undergraduate research. Council on Undergraduate Research Quarterly 37: 4–11. [CrossRef]


Spell, Rachelle M., Judith A. Guinan, Kristen R. Miller, and Christopher W. Beck. 2014. Redefining authentic research experiences in introductory biology laboratories and barriers to their implementation. CBE Life Sciences Education 13: 102–10. [CrossRef]

Thiry, Heather, and Sandra L. Laursen. 2011. The role of student-advisor interactions in apprenticing undergraduate researchers into a scientific community of practice. Journal of Science Education and Technology 20: 771–84. [CrossRef]


