Towards Making The Invisible Engineer Visible:

A Review of Low-Socioeconomic Students' Barriers Experiencing College STEM Education

Justin Major & Allison Godwin
Purdue University
Engineering Education
West Lafayette, Indiana, USA
major5@purdue.edu; godwina@purdue.edu

***Abstract*—This full research paper focuses on a systematized review of the literature on low-socioeconomic students in engineering. Increasing the diversity of engineering cannot be addressed without acknowledging the necessity for equity across socioeconomic groups. An important step to developing equitable pathways that allow low-socioeconomic students to engage in engineering education is by identifying barriers to participation. Because little is known about the "invisible" population of engineering, a literature review regarding low-socioeconomic students' participation in the larger STEM education context provides an opportunity to begin making the population visible. This work identifies barriers that may make participating in engineering difficult and provides suggestions for researchers and practitioners to work to remove them.**

Keywords—Low-Socioeconomic Students, Barriers, STEM Education, Post-Secondary Education, Equity in Education

I. Introduction

A body of research shows individuals who are socioeconomically advantaged are statistically more likely to receive a higher quality education, have appropriate physiological development, and to be of a higher status of health [1]–[4]. Results point to social inequities in students' opportunities for education and particular career pathways including engineering. In efforts to identify and, in the future, alleviate existing differences between socioeconomically diverse populations, national agendas surrounding research and education have been transformed to reflect the need to study the effects of socioeconomic status [5]–[7]. Within science, technology, engineering, and mathematics (STEM) education research, few studies on low-socioeconomic secondary or post-secondary students exist outside of studies at the intersection of socioeconomic status with race, gender, or international status, making the study of socioeconomic status as a separate factor in students pathways understudied [4]. For this reason, and low-socioeconomic students' lack of participation in engineering programs, Strutz, Orr, and Ohland [8] have referred to the population as an "invisible minority." Smith and Lucena [4] have further revised the term to "invisible innovators" noting assets the population can bring to engineering from the culture of poverty so long as practitioners lift the shroud and make their assets visible.

While STEM education research has not particularly focused on socioeconomically disadvantaged populations, a quantity of literature exists regarding this population in general education settings. Within this body, there are discussions of the classroom barriers economically disadvantaged students meet in general education settings. Findings from Bradley and Corwyn [2] and Bradley, Corwyn, McAdoo, and Garcia Coll [9] show that low-socioeconomic students often have less access to physical resources and less access to stimulating learning activities in the classroom. Additionally, they discuss the impact of teachers and other academic role models who inadvertently display differing attitudes towards students of lower socioeconomic background leading these students to fall behind in academic achievement and to be further behind in skills such as literacy [2], [4]. They claim that low-socioeconomic students may receive an education that is "different" from students who may even be in the same classroom [2]. These results pose additional questions about what additional academic barriers exist for those of low-socioeconomic backgrounds in STEM education environments and what effect it might have on their choice to continue exploring engineering.

Primarily, STEM education studies that do study socioeconomically disadvantaged populations search for differences in achievement, persistence, and opportunity [10], [11], but they often neglect to inform the STEM education field about the particular barriers socioeconomically disadvantaged students face participating in the STEM learning environment [4]. As a result, low-socioeconomic students are more likely to leave STEM all together in college than their peers [12]. It is critically important that we come to understand the barriers socioeconomically disadvantaged populations face in experiencing STEM education as they enter and complete college coursework.

While many previous studies on low-socioeconomic students focus on the consequences of students' low-income status on educational outcomes, they also examine socioeconomically disadvantaged students from a wide variety of frameworks and perspectives. Together, these results may allow us to create a clearer picture of how we can support low-socioeconomic students from a broader prospective. Thus, use of a systematized literature review may be both useful and

This work was funded by a National Science Foundation Graduate Research Fellowship (DGE-1333468). Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author and do not necessarily reflect the views of the National Science Foundation.

978-1-5386-1174-6/18/$31.00 ©2018 IEEE

necessary to add new and broader knowledge to the conversation of what barriers low-socioeconomic students experience learning STEM atop already-present general education barriers. Our results add to national conversations regarding the differentiation of educational practice to support the diverse population of students who experience it. This systematized review also provides reasoning for the field of engineering education to continue to pursue studies which seek to understand the experiences of low-socioeconomic students.

II. Methods

This systematized review follows procedures and recommendations of Lichtman [13] to identify, evaluate, organize, and disseminate data and results. The six steps within these procedures were to 1) identify a topic, 2) locate relevant literature, 3) read and evaluate literature, 4) critique that literature's research, 5) sort and organize contents of the research, and 6) disseminate findings. The process in which this review was completed is described below.

A. Topic Identification and Research Questions

The first step of this review was to determine a single subject of interest for this literature review. We were particularly interested in understanding the barriers that low-socioeconomic students face when pursuing degrees in engineering. However, little research exists regarding the experiences of these students, and thus our topic of interest was broadened to the larger STEM education field. We chose to focus on undergraduate students in the United States to understand how higher education may influence STEM students' pathways. In this systematized review, we answer the following research questions:

1. What barriers do post-secondary students from low-socioeconomic backgrounds face when participating in, experiencing, or learning about STEM concepts?

2. How might these barriers further motivate or challenge lower socioeconomic students' pursuit of engineering in post-secondary education?

For the purposes of better specifying the topic to the intended research questions, a list of exclusion criteria was developed that would be applied to the initial literature search, and manually as the review took place. We excluded literature that:

- did not study students directly in STEM, such as those within medicinal practice (i.e., nursing, medicine, etc.),
- did not study low-socioeconomic populations directly,
- did not study post-secondary students, or students of traditional college age (i.e., ages ~17 to 23),
- did not study students in the United States,
- did not publish in English, and
- did not publish in a peer-reviewed journal.

B. Database Choice

After the topic was chosen, we needed to specify the databases in which we would search. Two databases, EducationSource and Engineering Village, were used to search for related articles. EducationSource, with both subset database ERIC and Education Full Text, was used due to the database's wide collection of education-related articles. Additionally, Engineering Village, with both subset database Compendex and Inspec, was used due to the database's collection of articles related to engineering. After appropriate databases were selected, we developed the search keywords.

C. Search Keywords

To find literature on barriers faced by low-socioeconomic populations experiencing STEM, we developed a specific set of keywords that were applied to both databases. To specify the population of interest, words describing social status were determined to be important for limiting results to literature regarding a student's low-socioeconomic status. There are many ways in which low-socioeconomic status can be named, dependent on context and field, so we used multiple variations and choices to refer to low-socioeconomic students from the literature. Next, descriptions of STEM and its components (science, technology, engineering, and math) were considered to bound the topic to the context of STEM. However, throughout the development of the search string, the word "technology" became a problematic search term. The inclusion of this term found papers related to the development of technology rather than to technology as a discipline. Because of this issue, we removed the individual word "technology" from the keywords, but retained "STEM." Finally, to be even more specific, the population was specified as students within their respective age group. As many of the exclusion criteria could not be applied to this already limited topic without significantly limiting the results, the only keywords used were related to education specifically. The word "student" was necessary to exclude teachers and other adult figures. "Education" was necessary to limit studies to educational settings themselves. Additionally, we included keywords that focused the search on undergraduate students. The final categories of keywords were as follows:

- Status – low-socioeconomic, low socioeconomic, low income, low-income, low-SES, low SES, social status
- STEM – STEM, science, engineering, mathematics
- Population – student, undergraduate, college, post-secondary, post-secondary, education

D. Search Strings

Following a development of key terms, search strings were developed within the required formats of each chosen database. Each search string contains the necessary keywords. However, it is necessary to note that not all exclusion criteria related to the search could be put into the search string. EducationSource required that "Peer-Reviewed Journals" be selected manually, and Engineering Village required both that duplicates be deleted and articles be limited to English manually by clicking a box, as well. Each was done following the search. Final search strings can be seen in Appendix A of our appendices published as online supplemental materials [14].

E. Duplicates and Manual Application of Exclusion Criteria

Our search strings returned 24 results for EducationSource and 25 results for Engineering Village for a total of 49 articles. Results, including title, abstract, keywords, and author information, were printed and marked by hand to keep work organized before it would be put into electronic form. Overall citation storage was done using Mendeley Desktop [15]. Two articles, Doerschuk et al. [12], and Wilson and Kittleson [16], referenced in Appendix B of [14], were returned in both EducationSource and Engineering Village and therefore had one of each removed. A total of 47 articles remained thereafter.

After duplicate articles were removed, exclusion criteria were applied to the article's title and abstract. Information for each article was read and exclusion criteria were applied throughout. Ten articles were removed because the population of interest was outside of the United States. Berberoglu [17] and Talay, Gunduz, and Akpinar's [18] studies were situated in Turkey, Varma, and Kapur [19] in India, Selwyn [20] in United Kingdom, Chen [21] and Li, Yang, and Zhang [22] in China, Mansour [23] in Kuwait, Wang and Wong [24] in Singapore, and Benegas and Flores [25] in Argentina. The next group of six articles was removed for being outside the age group of interest. Landry et al.'s [26] population were described as being "toddlers." Additionally, Zhang [27] was removed as they described their population to be of elementary school age. Next, Dougherty, Goodman, Hill, Litke, and Page [28], Cabrera and Deil-amen [29], Delgado, Stevens, Shin, and Krajcik [30], and Russomanno [31] were removed as they had populations of primarily "middle school" age or referred to grades of their students being between 8th and 10th grade. In addition to removing papers that focused on students outside of the specified age range, we also removed two papers due to their populations being outside of the scope of criterion. Dukhan, Schumack, and Daniels [32] was removed as their study was not on low-socioeconomic students, but instead of higher socioeconomic students and their changing attitudes volunteering with lower socioeconomic students. Lastly, Bell [33] was removed as the study population was STEM librarians. A total of 18 articles, referenced in Appendix C of [14] were removed using these criteria leaving 29 articles.

The remaining 29 articles were read in full to determine if the studies met the inclusion and exclusion criteria. In a thorough read of the papers, an additional 11 articles were removed leaving a final total of 18 articles for systematized analysis. The first group of two papers was removed for having populations of study outside of the United States. Hanrahan [34] focuses on youth in Queensland while Wang [35] focuses on youth in Taiwan. The next five papers were removed for having populations outside of the included age group. Mueller and Maher [36] studied 6th-grade populations, Pinkard [37] studied K-8, and Austin [38], Case and Robert [39], and Dubinsky and Wilson [40] studied high school. Next, two articles were removed for not being peer-reviewed journal articles. Reedy [41] was found to be a company-sponsored magazine article, and Niu [42] was a full-length dissertation. Finally, the last two articles were removed for being related, but not close enough to the exclusionary criterion's needs. Toldson, Brown, and Sutton [43] discussed low-socioeconomic African Americans in the context of education, but not STEM education, and Elliott [44] studied youth populations of all ages but never specified how many students were within this study's age of interest. A list of the 11 removed articles and a final list of articles reviewed in this work can be found in Appendix D and Appendix E of [14], respectively.

F. Full Reading and Critical Evaluation of Literature

The remaining 18 articles were analyzed for overarching themes using Microsoft OneNote [45], which allows for electronic handwriting and file organization. In this analysis process, we coded for the article's methods, results, and the barriers for low-socioeconomic STEM students in higher education. We used a constant comparative coding approach to examine the results described in each paper and to iteratively examine emerging themes across the papers. We continued our analysis until all 18 papers had been analyzed and there was agreement among each coder. We kept careful documentation of each file for transparency in developing the final themes.

III. Findings and Discussion

This systematized review found three themes across observed literature: 1) low-socioeconomic students lack buy-in from others that their pursuit matters, 2) the differing interests, values, and goals of low-socioeconomic students in comparison to peers are not valued or supported by STEM, 3) and participating in STEM has more adverse costs for low-socioeconomic students than their peers.

A. Theme 1: Low-Socioeconomic Students Lack Buy-In From Others That Their Pursuit Matters

While low-socioeconomic students are often first categorized based on their lack of monetary capital [4], they often face challenge beyond financial considerations. Wilson and Moritz [46] discussed this trend in the context of the *Teach for America* computer science program. They discussed how low-socioeconomic students often also lack the support needed from academics such as principals and teachers to provide appropriate STEM education, leading to a lack of qualified curriculum and teachers that support student needs. Byun, Irvin, and Bell [47] also agreed with this conclusion. They argued that while money can be an important factor in what a school can provide, teachers with a rigorous mathematics background as well as the motivation and know-how to teach underrepresented population are not present in the schools that need them most. Often, these teachers purposely chose to remain in schools of higher socioeconomic status [32], even in schools that have the necessary money to provide STEM opportunities, Byun, Irvin, and Bell [47], Wilson and Moritz [46] and Varma [48] showed that programs in both computer science and mathematics contexts are known to differ in rigor too. Their work found a clear difference between the advanced courses in lower socioeconomic educational systems and those of higher socioeconomic. Quoting Riegle-Crumb and Grodsky [49], Byun, Irvin, and Bell [47] stated that "the advanced courses available to underrepresented youth are advanced in name but not in substance" (p. 249). This theme was present across a number of papers in this review for both secondary and post-secondary schools, and also home communities.

Not only the necessary buy-in and support for low-socioeconomic students not present in schools, but at times, these vital structures are also missing in these students' communities. Varma [48] discussed this issue in his analysis of low-socioeconomic Native American populations participating in computer science. He pointed out that students felt that their home communities did not see or understand the importance of STEM education, and sometimes post-secondary education as a whole, leaving the student to experience STEM in "alienation" [48, p. 139]. These feelings of alienation were present from student peers in the post-secondary STEM environment too. Students shared that "They [peers] look down on you … like what are you doing here? … Sometimes there is over sympathy … and sometimes too much appreciation just for the fact that you are a Native American in computer science. There is never a middle ground" [46, p. 139]. This lack of buy-in in the classroom can position low-socioeconomic students as feeling like STEM is "not for people like them." This facet of the lack of buy-in theme is not only present in cultural communities but also for families of first-generation students.

Wilson and Kittleson [16] discussed two students, Judy and Jamie, who identified as white, as female, as low-income, and as first-generation students. Jamie and Judy struggled throughout college to feel like their pursuit of a STEM degree was worth the effort. They had friends and family ask them repeatedly why they were pursuing their degrees, tell them their pursuit was a waste, and that they, as Jamie said within the article, should "hurry up and get married [to be] someone else's problem" [15, p. 816]. Additionally, Jamie pointed out that she felt like her family thought that "[college was] like a burden that I've put on myself for no reason" [15, p. 816]. Not only did Jamie's statement represent a lack of familial buy-in that obtaining a college degree is valuable, but it also represented the appropriation of degrees in STEM, if not college as a whole, as a middle-upper class masculine enterprise. These results are problematic for students who do not belong to "normative" white, male, middle-upper classed groups [50], and do not receive powerful positive buy-in.

While positive buy-in is often lacking in the home and peer communities of low-socioeconomic students, research on communities that do acknowledge the pursuit of a STEM degree as meaningful see positive results. Amstutz, Wimbush, and Snyder [51] discussed an undergraduate tutoring center specific for underrepresented students and the differences it made in student motivation. They pointed out in their qualitative work that students chose to visit the tutoring center to work with specific tutors who were more invested in students' personal success than other tutors who just saw tutoring as a job without purpose. Leggett-Robinson, Mooring, and Villa [52] discussed success with a program at Georgia Institute of Technology in which students attended preparatory classes and participated in research alongside faculty and other students who mentored them and gave them feedback throughout. While they attributed the success of the students in choosing STEM majors to the program, there was a clear discussion from the students that buy-in from faculty and staff that supported their STEM interests was key to their success in the program and beyond. Similar results on the impact of specific programs was shown in a study of the Julian Scholars program at DePauw University [50]. Students described the program director and mentors of the program as people who cared for their well-being in their success and as a major reason for their ability to navigate their experiences in STEM. Zimmerman, Johnson, Wambsgans, and Fuentes [53] discussed the "La Familia" (meaning "family" in Spanish) aspect of a low-socioeconomic Hispanic-serving institution in which community played a huge role in the success of the students. Students within the community felt that they belonged with their peers who were from similar backgrounds and who had similar interests. Additionally, students felt that faculty partnerships with them provided them feelings that there was investment in their worth and pursuit of a degree in STEM.

Smith and Lucena [4] and Martin, Miller, and Simmons [54] both suggested that low-socioeconomic students need validation that what they bring to STEM has value and that validation comes from buy-in from all individuals who have a connection to low-socioeconomic communities; family, friends, teachers, educational administration, and more. Martin, Miller, and Simmons [54] suggest that first-generation students, widely including populations of low-socioeconomic students, may have more individuals who can validate their pursuit than others student groups. However, this theme describes the problematic nature that though these communities exist, the support necessary to continuously foster low-socioeconomic STEM identities is simply not present.

B. Theme 2: Differing Interests, Values, and Goals of Low-Socioeconomic Students in Comparison to Peers Are Not Valued or Supported by STEM

Not only do low-socioeconomic students lack buy-in that their pursuit of STEM is worth it, but many of the students who pursue STEM did not see the different STEM interests, values, and goals they bring to pursuing STEM as valued. Smith and Lucena [4] explained that unlike higher socioeconomic counterparts, low-socioeconomic students are often more likely to bring culturally-related pursuits with them that have value to them beyond their education. Smith and Lucena [4] in discussion of the popular "Inez" study [52] concluded that socioeconomic status and lack of wealth is often the most salient identity across racial minority groups [4], [46] as a culture of its own. From students' varying cultures, including the culture they bring from different racial/ethnic backgrounds or the culture they bring from socioeconomic identities, studies in and out of this work report the mismatch between students' cultural values, goals, and interests with the values of the STEM culture, which most often solely values technical skills.

Smith and Lucena [4] studied the concurrent home and school lives of low-socioeconomic students using ethnographic interviews and found that the students they interviewed had a variety of goals, skills, and interests that did not match what the field of engineering valued. These students valued working with their hands, helping others, changing the world, and seeking a career pathway for upward social mobility while engineering mostly values technical prestige [4]. Through these students' experiences in their STEM courses, the authors found that students' class-cultural values did not match what STEM curriculum and careers have in mind. Specifically, STEM careers emphasized technical skills and innovative progress at the forefront and often ignored the social connection and global impact that low-socioeconomic students valued. The same emphasis in engineering curricula was found by Conrad, Canetto, Macphee, and Farro [55] in their survey of students participating in the McNair program, a program which seeks to support underrepresented students in graduate programs such as low-socioeconomic students. In this study, students displayed a passion for scientific research, saw engineering as a way to help their communities, believed engineering careers brought financial security, enjoyed STEM subjects, and saw pursuing STEM as a way to continue having positive outcomes. However, students claimed that their values and interests were not valued by normative STEM curriculum. For some STEM students, a mismatch between their expectations of STEM and their experiences were particularly important in their satisfaction in their degree programs.

The mismatch between what STEM fields value and what students value from their home cultures was made most clear by Varma [48]. Native American students saw value in their communities and saw STEM as a mismatched to their culture because jobs were not readily available near their homes on reservations. Additionally, these students felt that "the importance of family, home, community, tribal duties, and philosophy outweigh[ed] educational cultures" [46, p. 139] and that "holding on to native customs, language, and traditions" [46, p. 139] challenged their pursuit of computer science. These students felt that because STEM culture did not appreciate students' home culture, students were left feeling like they had to juggle these two worlds separately.

Lee, Daniels, Puig, Newgent, and Nam [56] also discussed the implications of students experiencing a mismatch between the values of STEM and their own values. From their results, they posited that students who felt this mismatch did not have a "locus of control" and felt unable to navigate their pathways into and through engineering. Thus, they claimed that students rejected STEM pathways outright to regain the control they felt they lost, narrating a complex boundary which low-socioeconomic students must navigate if they are to continue in STEM pathways.

The participants in Leggett-Robinson, Mooring, and Villa [52] described feeling like their own values and goals could be supported by STEM Particularly, students discussed how STEM experiences helped them develop knowledge and to get important experiences "under their belt" [49, p. 3]. In developing these skills, students had confidence doing science that was practical for their futures. The authors suggested that their participants were lucky though and that similar experiences are often missing from curriculum, causing a majority of students to miss out on opportunities to see themselves as a STEM person [49]. Positive results of participation were also discussed by Amstutz, Wimbush, and Snyder [51] who found that students who participated in tutoring to achieve their personal goals had higher academic integration and success. These students saw tutors as individuals that had particular important knowledge that they were unable to otherwise obtain from coursework. These experiences may have only been made possible had students seen a match between STEM curriculum and their own goals.

While students in a few of these studies mentioned the importance of participating in these programs to the attainment of their differing goals, the perception of usefulness of STEM to personal goals is not always commonplace. Non-congruence of usefulness to goals was shown in interviews by Fadigan and Hammrich [50]. The young women in their study discuss loving the learning they receive from learning experiences, but did not see it as useful to their future careers or could not see themselves doing it as a part of their future career interests. Thus, they suggested that researchers and educators should acknowledge that students have many ways and reasons to pursue STEM, and that all of these ways and reasons should be valued in STEM classrooms

This theme points out the differences that exist between the values that STEM curriculum values, and the values and goals that students bring into the classroom. Sometimes these differences may be due to cultural differences, but Wilson and Kittleson [16] also warned against this being the only way to view difference. They suggested that viewing differences as solely culturally based is supportive of a normative culture of "whiteness." This perspective puts non-white students in contrast to the norm of whiteness, which is commonly constructed in engineering as cultureless. In their comments on the whiteness that envelopes the STEM disciplines, they suggest that the underlying features of differing values are not a result of culture being present, but that white culture seeks to disempower values that are not congruent with white values. To empower all voices in the STEM classroom, Wilson and Kittleson [16] recommended that the differences that exist between values and goals of students and the values in the STEM classroom also be viewed at as a failure of STEM curriculum to be inclusive of other students' needs.

C. *Theme 3: Participating in STEM Has More Adverse Costs for Low-Socioeconomic Students Than Their Peers*

While low-socioeconomic students are whole people who are not solely defined by their class, cost was at the forefront of their choices in their STEM pathways. Quadlin [57] analyzed student records and found that as tuition rates went up, students were less likely to enroll in STEM programs. Additionally, as funding sources changed and students had less certainty about their ability to complete college, students left STEM to pursue degrees that would ensure their ability to move out of the lower class noting that "failure in STEM is costly" Quadlin [55, p. 96]. George-Jackson, Rincon, and Martinez [58] found similar results. Extra fees that are often associated with STEM program enrollment, often called "differential fees," affected low-socioeconomic students abilities to complete programs because of costs over time. At the start of enrollment, most programs included the fees in tuition breakdowns and financial aid that was offered to students. However, over time, financial aid was reduced, and differential fees increased, leaving low-socioeconomic students to reconsider the choice of STEM.

For low-socioeconomic students, failure in their degree programs is not an option, and they leave when the costs increase [57]. These costs are not only financial but related to time in a STEM degree program as well. Varma [48] found that the cost of time was important to students who had external jobs to support themselves or their families or had responsibilities to their tribes or families. Amstutz, Wimbush, and Snyder [51] also discussed the importance of time for low-socioeconomic students. If students chose to attend tutoring, they attended at specific times of day when they did not have to work. Often, students discussed not attending tutoring at all because it conflicted with other responsibilities [51]. Although only a few articles directly discussed the importance of cost, costs of time became a reoccurring topic in some way in nearly every article of this review. Cost is salient to the identity of being a low-socioeconomic student and should be considered when working with this population.

Cost is still an important factor for low-socioeconomic students to participant in STEM. Whether these costs are monetary or time related, or whether costs directly or indirectly affect low-socioeconomic students, such as with the case of purchasing in schools to provide opportunity, cost of participation should always be considered.

IV. Discussion of Research Questions

This systematized review found three primary themes in the current literature on low-socioeconomic STEM students in higher education: 1) low-socioeconomic students lack buy-in from others that their pursuit matters, 2) the differing interests, values, and goals of low-socioeconomic students in comparison to peers are not valued or supported by STEM, 3) and participating in STEM has more adverse costs for low-socioeconomic students than their peers. The identification of these themes better informs understanding of the barriers low-socioeconomic students meet in their pursuit of STEM degrees.

A. RQ 1) What barriers do post-secondary students from low-socioeconomic backgrounds face when participating in, experiencing, or learning about STEM concepts?

When participating in, experiencing, or learning about STEM, low-socioeconomic students often meet barriers related to the support and resources they receive, the congruence they see between their own values and goals and those of STEM education, and the costs they must take on to participate.

The literature demonstrates that low-socioeconomic students do not receive the proper educational support necessary to participate in STEM learning. Many schools either do not provide necessary opportunities to experience STEM at all [11], or the opportunities they receive are laden in or misconceptions about teaching STEM (such as teaching a class that is thought to be a high-level STEM class that may only be teaching lower level STEM concepts [47]). When opportunities to experience STEM are not present at all, students may not be interested in or feel confident in pursuing a STEM pathway in the future. Additionally, students' perceptions of a course that teaches high-level concepts at a low level as easy may adversely affect low-socioeconomic students' self-concept when they meet difficulties with STEM achievement [47].

In-school issues do not stop at providing opportunities for low-socioeconomic students to experience STEM. Students also need strong academic support networks to be successful. Teachers, tutors, and principals in low-socioeconomic schools may not be qualified or invested in providing the guidance necessary to ensure academic success for low-socioeconomic students [47] and may adversely affect students of feeling like they should be involved in STEM. Additionally, teachers may not encourage low-socioeconomic to pursue STEM beyond class [11]. Issues with support may also exist in other aspects of low-socioeconomic students' support networks too. At home, low-socioeconomic students may be positioned as wasting their time pursuing STEM instead of doing another major or participating in home communities [48]. With peer groups, problematic positioning may cause students to feel like they do not belong in STEM or in college at all. This negative encouragement can continue to bar low-socioeconomic students from choosing to participate in STEM.

Cost is a significant barrier for low-socioeconomic students. Cost is not only related to money, but also to time. In relation to money, cost of attendance continues to be too high for low-socioeconomic students to attend without assistance [57]. Cost changes should be considered once students are in college as well. Once in college, changes in tuition can cause students to reconsider pathways through STEM because of the costs and risks associated. Additionally, the addition of differential fees to tuition statements can make the process of pursuing STEM much more difficult [58]. In relation to time, tasks such as studying or projects may be associated as a risk for low-socioeconomic students who feel their time is needed for other aspects of their lives such as working or taking care of children [50]. These costs may make low-socioeconomic students feel that their pursuit of STEM may be too risky [57].

B. RQ 2) How might these barriers further motivate or challenge low-socioeconomic students' pursuit of engineering in post-secondary education?

Each barrier described in the literature is closely linked to discussions of recruitment and retention of low-socioeconomic students in engineering programs. Students are unlikely to pursue engineering if they feel that the endeavor does not have value to them [59] or if they do not belong in engineering [4]. These feelings may come from a lack of buy-in from significant people in their lives (e.g., teachers, family, friends, etc.) or encouragement. When low-socioeconomic students' pursuit of engineering goes unsupported, they often choose non-STEM majors or skip going to college at all. For those already in engineering, lack of continued support is considered a reason why students leave [60]. Additionally, when students do not have support from others that they can bring something to engineering [4], they may consider leaving engineering [61] because they do not feel competent in their abilities or recognized as being a STEM person, both important for the formation of identity [62] and retention in engineering [60].

When students come to engineering, they bring a variety of identities and values with them including those that are culturally based [4], [62]. Commonly, these cultures are not included as a part of the classroom experience, but not considering cultural influences can instead ostracize students and make them feel like they do not belong because of qualities of who they are [4], [50]. Instead of separating culture from STEM teaching experiences, culture should be intertwined [63]. If we do not acknowledge that the multi-faceted identities of low-socioeconomic students are important to engineering, we risk these students feeling like they do not belong and eventually leaving [4], [64]. Additionally, there is a need for researchers to identify the ways in which engineering, and the engineering classroom, continues to support white, masculine, upper-middle class norms [63], as these norms may negate the varying altruistic goals and values that low-socioeconomic students bring to engineering [4]. Pawley [63] suggests that differences in the way that faculty and minoritized groups define engineering further problematizes pathways for students to enter engineering. An identification of these differences by class may help determine the boundaries that exist to keep low-socioeconomic students out of engineering.

V. LIMITATIONS

We recognize that leaving out "technology" as a search term may have limited the scope of the themes in this work. The absence of other potential words that may have been useful to describe the population of interest may have altered the number of results that were returned and were thereafter analyzed for this work. Additionally, other articles of interest that exist outside of United States contexts were written in other languages, or were within other age populations besides college populations could have broadened our understanding of low-socioeconomic students. Another limitation of this work may come from its origination as a class project which required there be no more than 100 sources appear with the final search string. This limitation may have caused over-simplification of criteria or may have limited databases that could have more provided articles of interest.

VI. CONCLUSION, IMPLICATIONS, & FUTURE WORK

The presented systematized review reviewed 18 articles in hopes to discover a better understanding of the barriers low-socioeconomic students meet experiencing STEM, and to discover how these barriers may further prevent low-socioeconomic students pursuing engineering from continuing. From review, three primary themes were found: 1) that low-socioeconomic students lack buy-in from others that their pursuit matters, 2) that the differing interests, values, and goals of low-socioeconomic students in comparison to peers are not valued or supported by STEM, 3) and that participating in STEM has more adverse costs for low-socioeconomic students than their peers. These three themes can each be related to barriers low-socioeconomic students face pursuing STEM; each can make low-socioeconomic students feel like they should not or cannot belong to STEM because of their racial/ethnic or socioeconomic identities. In engineering, this change in conversation can be the difference between a student identifying as an engineer and choosing to persist, or leaving engineering all together to pursue non-STEM careers [60].

Both before and in college, low-socioeconomic students need encouragement that their pursuit matters, indication that the values and goals they bring from cultural backgrounds deserve to have a voice in the STEM classroom and help to navigate the many costs that exist to pursuing a degree in STEM. Members both in and out of school support networks need to be educated about how to properly support low-socioeconomic students. Additionally, parents in low-socioeconomic communities need to be informed about the importance of encouragement and provide resources that they can use to help low-socioeconomic students succeed.

Teachers are who are trained and invested in helping low-socioeconomic students must be placed in the classrooms that need them most. Additionally, these teachers need to be trained to show students how to navigate complex college support structures, such as financial, to achieve college access and degree attainment. Outside of teachers, STEM education also needs to be restructured to allow for better inclusivity of the multi-faceted identities that are brought by those of diverse backgrounds such as low-socioeconomic students. This can be accomplished by presenting various ways of doing engineering and being an engineer in the classroom. Lastly, the costs of pursuing engineering, if not college as a whole, must be reevaluated to better support low-socioeconomic students who find engineering difficult to pay for, or find it difficult to do because of the costs of time included.

Future work will continue to identify barriers low-socioeconomic students face pursuing in their attempt to participate in engineering. Additionally, work will seek to understand how low-socioeconomic students in engineering navigate non-inclusive structures, and how that understanding can inform the creation of more equitable pathways for low-socioeconomic students in engineering.

ACKNOWLEDGMENTS

The authors would like to thank librarian Amy Van Epps at Harvard University for her guidance in developing initial database search strings, and the graduate students of ENE 503 at Purdue University for their advice and feedback in the early stages of this work.

REFERENCES

[1] T. Leventhal and J. Brooks-Gunn, "The neighborhoods they live in: The effects of neighborhood residence on child and adolescent outcomes.," *Psychological Bulletin*, vol. 126, no. 2, pp. 309–337, 2000.

[2] R. H. Bradley and R. F. Corwyn, "Socioeconomic status and child development," *Annual Review of Psychology*, vol. 53, no. 1, pp. 371–399, 2002.

[3] D. R. Williams, S. A. Mohammed, J. Leavell, and C. Collins, "Race, socioeconomic status, and health: Complexities, ongoing challenges, and research opportunities," *Annals of the New York Academy of Sciences*, vol. 1186. pp. 69–101, 2010.

[4] J. M. Smith and J. C. Lucena, “Invisible innovators: how low-income, first-generation students use their funds of knowledge to belong in engineering,” *Engineering Studies*, vol. 8, no. 1, pp. 1–26, 2016.

[5] President’s Council of Advisors on Science and Technology, “Engage to excel: Producing one million additional college graduates with degrees In science, technology, engineering, and mathematics,” 2012.

[6] National Science Foundation, “Investing in science, engineering, and education for the Nation’s Future,” *NSF Strategic Plan for 2014 – 2018*, 2014.

[7] The Executive Office of the President, “Increasing college opportunity for low-income students: Promising models and a call to action,” 2014.

[8] M. L. Strutz, M. K. Orr, and M. W. Ohland, “Low socioeconomic status individuals: An invisible minority in engineering,” in *Engineering and Social Justice: In the University and Beyond*, C. Ballie, A. Pawley, and D. Riley, Eds. Purdue University Press, 2008, pp. 143–156.

[9] R. H. Bradley, R. F. Corwyn, H. P. McAdoo, and C. Garcia Coll, “The home environments of children in the United States part I: Variations by age, ethnicity, and poverty status,” *Child Development*, vol. 72, no. 6, pp. 1844–1867, 2001.

[10] M. K. Orr, N. M. Ramirez, and M. Ohland, “Socioeconomic Trends in Engineering : Enrollment , Persistence , and Academic Achievement,” *American Society for Engineering Education*, 2011.

[11] J. C. Major, A. Godwin, G. Sonnert, and P. M. Sadler, “STEM experiences of engineering students from low-socioeconomic neighborhoods,” *2018 ASEE Annual Conference & Exposition*, 2018.

[12] P. Doerschuk, C. Bahrim, J. Daniel, J. Kruger, J. Mann, and C. Martin, “Closing the gaps and filling the STEM pipeline: A multidisciplinary approach,” *Journal of Science Education and Technology*, vol. 25, no. 4, pp. 682–695, 2016.

[13] M. Lichtman, *Qualitative Research in Education: A User’s Guide*, 3rd Editio. Thousand Oaks, CA: Sage Publications, 2013.

[14] J. C. Major and A. Godwin, “Systematized Review Supplemental Information,” 2018. [Online]. Available: https://sites.google.com/site/fie2018systematizedreview/.

[15] The Mendeley Support Team *et al.*, “Mendeley Desktop,” *Mendeley Desktop*, vol. 257, no. November. pp. 1–16, 2011.

[16] R. E. Wilson and J. Kittleson, “Science as a classed and gendered endeavor: Persistence of two white female first-generation college students within an undergraduate science context,” *Journal of Research in Science Teaching*, vol. 50, no. 7, pp. 802–825, 2013.

[17] G. Berberoglu, “Differential item functioning (DIF) analysis of computation, word problem and geometry questions across gender and SES groups,” *Studies in Educational Evaluation*, vol. 21, no. 4, pp. 439–456, 1995.

[18] I. Talay, S. Gunduz, and N. Akpinar, “On the status of environmental education and awareness of undergraduate students at Ankara University, Turkey,” *International Journal of Environment and Pollution*, vol. 21, no. 3, pp. 293–308, 2004.

[19] R. Varma and D. Kapur, “Access, satisfaction, and future: Undergraduate education at the Indian Institutes of Technology,” *Higher Education*, vol. 59, no. 6, pp. 703–717, 2010.

[20] N. Selwyn, “e-Learning or she-learning? Exploring students’ gendered perceptions of education technology: Colloquium,” in *British Journal of Educational Technology*, 2007, vol. 38, no. 4, pp. 744–746.

[21] Y. Chen, “The construction of the core socialist values education model innovation of college students,” *Agro Food Industry Hi-Tech* , vol. 28, no. 3, pp. 2840–2844, 2017.

[22] S. Li, C. Yang, and Y. Zhang, “A survey on the present situation of students’ educational technology ability at a normal college,” *World Transactions on Engineering and Technology Education*, vol. 11, no. 4, pp. 521–526, 2013.

[23] E. A. H. Mansour, “The use of Social Networking Sites (SNSs) by the faculty members of the School of Library & Information Science, PAAET, Kuwait,” *The Electronic Library*, vol. 33, no. 3, pp. 524–546, 2015.

[24] C. K. Wang and P. K. Wong, “Entrepreneurial interest of university students in Singapore,” *Technovation*, vol. 24, no. 2, pp. 163–172, 2004.

[25] J. Benegas and J. S. Flores, “Effectiveness of tutorials for introductory physics in Argentinean high schools,” *Physics Education Researc*, vol. 10, no. 1, 2014.

[26] Landry et al., “Enhancing early child care quality and learning for toddlers at risk: The responsive early childhood program.,” *Developmental Psychology*, vol. 50, no. 2, pp. 526–541, 2014.

[27] M. Zhang, “Understanding the relationships between interest in online math games and academic performance,” *Journal of Computer Assisted Learning*, vol. 31, no. 3, pp. 254–267, 2015.

[28] S. M. Dougherty, J. S. Goodman, D. V. Hill, E. G. Litke, and L. C. Page, “Objective course placement and college readiness: Evidence from targeted middle school math acceleration,” *Economics of Education Review*, vol. 58, pp. 141–161, 2017.

[29] A. F. Cabrera and R. Deil-amen, “Increasing the college preparedness of at-risk students,” *Journal of Latinos and Education*, vol. 5, no. 2, pp. 79–97, 2009.

[30] C. Delgado, S. Y. Stevens, N. Shin, and J. Krajcik, “A middle school instructional unit for size and scale contextualized in nanotechnology,” *Nanotechnology Reviews*, vol. 4, no. 1, pp. 51–69, 2015.

[31] D. J. Russomanno, “Computer fundamentals: A gear-up experience for K-12,” *Computers in Education Journal*, vol. 14, no. 1, pp. 38–45, 2004.

[32] N. Dukhan, M. R. Schumack, and J. J. Daniels, “Service learning as pedagogy for promoting social awareness of mechanical engineering students,” *International Journal of Mechanical Engineering Education*, vol. 37, no. 1, pp. 78–86, 2009.

[33] S. J. Bell, “Online or out the door: Continuous learning for academic librarians in economic downturns,” *Library Issues*, vol. 29, no. 5, pp. 1–4, 2009.

[34] M. Hanrahan, “Rethinking science literacy: Enhancing communication and participation in school science through affirmational dialogue journal writing,” *Journal of Research in Science Teaching*, vol. 36, no. 6, pp. 699–717, 1999.

[35] T. Wang, “A conceptual model for assessin the impacts of gender issues on technology education,” *International Journal Of Organizational Innovation*, vol. 3, no. 3, pp. 278–286, 2011.

[36] M. Mueller and C. Maher, “Learning to reason in an informal math after-school program,” *Mathematics Education Research Journal*, vol. 21, no. 3, pp. 7–35, 2009.

[37] N. Pinkard, “How the perceived masculinity and/or femininity of software applications influences students’ software preferences,” *Journal of Educational Computing Research*, vol. 32, no. 1, pp. 57–78, 2005.

[38] C. Y. Austin, “Perceived factors that influence career decision self-efficacy and engineering related goal intentions of African American high school students,” *Career & Technical Education Research*, vol. 35, no. 3, pp. 119–135, 2010.

[39] Case and Robert, “Connecting the university to inner-city secondary school mathematics,” *Jun*, vol. 12, no. 2, 2002.

[40] E. Dubinsky and R. T. Wilson, “High school students’ understanding of the function concept,” *The Journal of Mathematical Behavior*, vol. 32, no. 1, pp. 83–101, 2013.

[41] S. Reedy, “Carriers build givers’ networks,” *Telephony*, vol. 247, no. 14, pp. 18–22, 2006.

[42] L. Niu, “Choosing an undergraduate STEM major: Family socioeconomic status, individual, and institutional factors,” 2013.

[43] I. A. Toldson, R. L. F. Brown, and R. M. Sutton, “Commentary: 75 Years after the ‘mis-education of the negro’: New imperatives for the education of Black males,” *The Journal of Negro Education*, vol. 78, no. 3, pp. 195–203, 2009.

[44] W. Elliott, "Children's college aspirations and expectations: The potential role of children's development accounts (CDAs)," *Children and Youth Services Review*, vol. 31, no. 2, pp. 274–283, 2009.

[45] Microsoft Corporation, "Microsoft OneNote | The digital note-taking app for your devices," 2017. [Online]. Available: https://www.onenote.com/.

[46] J. P. Wilson and M. Moritz, "Helping high-needs schools prioritize cs education through teacher advocacy & experiences," *ACM Inroads*, vol. 6, no. 3, pp. 73–74, 2015.

[47] S. Y. Byun, M. J. Irvin, and B. A. Bell, "Advanced math course taking: Effects on math achievement and college enrollment," *Journal of Experimental Education*, vol. 83, no. 4, pp. 439–468, 2015.

[48] R. Varma, "Attracting Native Americans to computing," *Communications of the ACM*, vol. 52, no. 8, p. 137, 2009.

[49] C. Riegle-Crumb and E. Grodsky, "Racial-ethnic differences at the intersection of math course-taking and achievement," *Sociology of Education*, vol. 83, no. 3, pp. 248–270, 2010.

[50] K. A. Fadigan and P. L. Hammrich, "A longitudinal study of the educational and career trajectories of female participants of an urban informal science education program," *Journal of Research in Science Teaching*, vol. 41, no. 8, pp. 835–860, 2004.

[51] M. Amstutz, K. Wimbush, and D. Snyder, "Effectiveness and student demographics of peer-led study groups in undergraduate animal science courses," *NACTA Journal*, pp. 76–81, 2010.

[52] P. M. Leggett-Robinson, S. R. Mooring, and B. C. Villa, "A 3+8 model of undergraduate research for community college STEM majors," *Journal of College Science Teaching*, vol. 44. National Science Teachers Association, pp. 12–18, 2015.

[53] T. G. Zimmerman, D. Johnson, C. Wambsgans, and A. Fuentes, "Why Latino high school students select computer science as a major: Analysis of a success story," *ACM Transactions on Computing Education*, vol. 11, no. 2, pp. 1–17, 2011.

[54] J. Martin, M. Miller, and D. Simmons, "Exploring the theoretical social capital '"deficit"' of first generation college students: Implications for engineering education," *International Journal of Engineering Education*, vol. 30, no. 4, pp. 822–836, 2014.

[55] S. Conrad, S. S. Canetto, D. Macphee, and S. Farro, "What attracts high-achieving, socioeconomically disadvantaged students to the physical sciences and engineering?," *College Student Journal*, vol. 43, no. 4, pp. 1359–1372, 2009.

[56] S. M. Lee, M. H. Daniels, A. Puig, R. a. Newgent, and S. K. Nam, "A data-based model to predict postsecondary educational attainment of low-socioeconomic-status students," *Professional School Counseling*, vol. 11, pp. 306–316, 2010.

[57] N. Quadlin, "Funding sources, family income, and fields of study in college," *Social Forces*, vol. 96, no. 1, pp. 91–120, Sep. 2017.

[58] C. E. George-Jackson, B. Rincon, and M. G. Martinez, "Low-income engineering students: Considering financial aid and differential tuition," *Journal of Student Financial Aid*, vol. 42, no. 2, pp. 4–24, 2012.

[59] A. Wigfield, S. Tonks, and S. L. Klauda, "Expectancy-value theory," in *Handbook of Motivation at School*, 2009, pp. 55–75.

[60] R. Marra, K. Rodgers, D. Shen, and B. Bogue, "Leaving engineering: A multi-year single institution study," *Journal of Engineering Education*, vol. 101, no. 1, pp. 6–27, 2012.

[61] A. Godwin and G. Potvin, "Pushing and pulling Sara: A case study of the contrasting influences of high school and university experiences on engineering agency, identity, and participation," *Journal of Research in Science Teaching*, vol. 54, no. 4, pp. 439–462, 2017.

[62] A. Godwin, G. Potvin, Z. Hazari, and R. Lock, "Identity, critical agency, and engineering: An affective model for predicting engineering as a career choice," *Journal of Engineering Education*, vol. 105, no. 2, pp. 312–340, 2016.

[63] A. L. Pawley, "Universalized narratives: Patterns in how faculty members define 'engineering,'" *Journal of Engineering Education*, vol. 98, no. 4, pp. 309–319, 2013.

[64] C. E. Foor, S. E. Walden, and D. A. Trytten, ""I wish that I belonged more in this whole engineering group:" Achieving individual diversity," *Journal of Engineering Education*, vol. 96, no. 2, pp. 103–115, 2007.