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A Systematic Literature Review on Improving Success of Women Engineering Students in the United States

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A systematic literature review on improving success of UG woman engineering students in the US

Introduction

Over the past three decades, women in the Unites States (US) have outpaced men in higher education enrollment and degree obtainment[1]. However, their representation in STEM (Science, Technology, Engineering, and Mathematics) fields, and especially in the engineering field, has significant scope for improvement[2] [3]. Figure 1 provides the percentage engineering bachelor's degrees awarded to female students of all engineering bachelor's degrees in the US from 2006 to 2014. While the earlier downward trend is reversed, the significant underrepresentation of women in engineering remains.

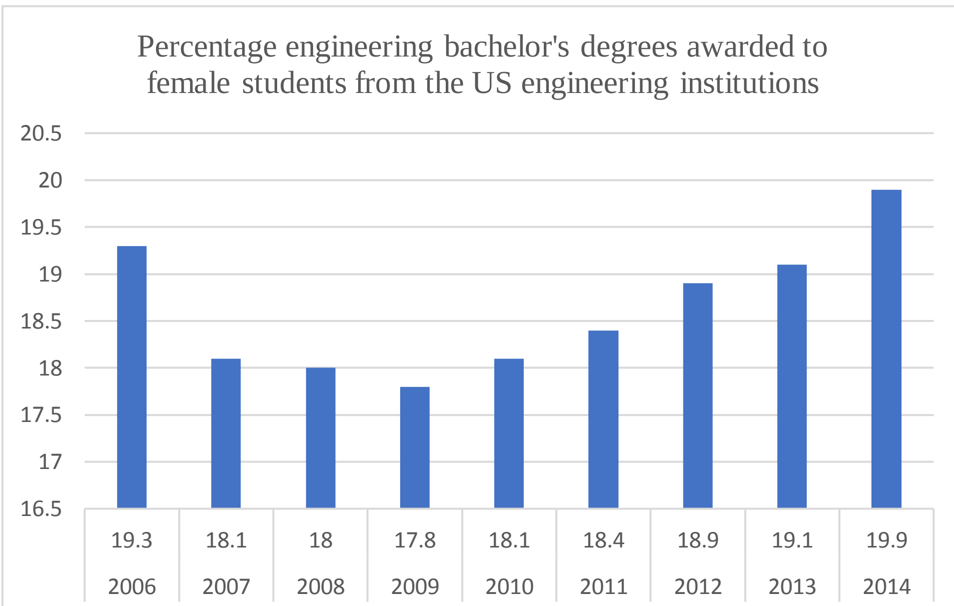

Figure 1: Percentage of engineering bachelor's degrees awarded to female students of all engineering bachelor's degrees from the US engineering institutions (2006-2014). (The X-axis has years and Y-axis has the percentage of degrees awarded to female students of all engineering bachelor's degrees from the US engineering institutions)

The underrepresentation of women creates a lack of diversity in engineering workforce and hampers development of innovative and customer-centric solutions. It appears to be due to poor recruitment and retention. For this study, we consider retention, six-year graduation, and academic performance as constituting success of women engineering students, which many researchers have studied. A systematic review of these numerous studies, which analyzes various research findings can help educators and administrators understand and boost the success of women in engineering education. That is the objective of the paper and towards that we systematically review papers published in the Journal of Engineering Education (JEE) from 1993 through 2016 that claimed to study gender and success within undergraduate engineering programs in the US.

Methodology

Like any systematic review, this study organizes, evaluates, and synthesizes literature; identifies patterns, trends, and research gaps; recommends new research areas[4]; and provides comprehensive landscapes based on multiple studies, which can expedite further research in the area[5]. The review process is summarized in figure 2.

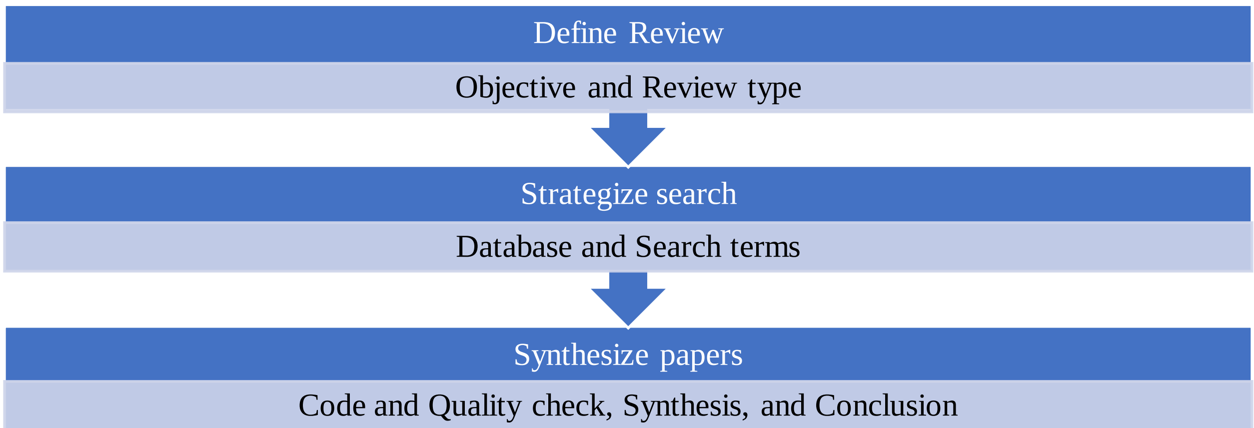

Figure 2: Systematic Review Method

Define Review

Objective

The objective of our study is to systematically review literature on improving the success of women students in undergraduate engineering in the US.

Review Type

Reviews can be broadly classified as narrative reviews and systematic reviews[4]. This paper undertakes a systematic review, which is characterized by more formalized procedures for searching, selecting, coding, and synthesizing literature[6]. Finfgeld expects systematic reviews to produce a new and integrative interpretation of findings that is more substantive than those resulting from individual investigations[7]. Borrego et al. consider systematic reviews to be a promising approach to advance the field as it synthesizes prior work. The synthesis, they say, can potentially lead to improved theoretical foundations, to the use of better informed practices, and to identification of new research directions[8].

Reviews can also be broadly classified as status quo reviews that present the most current research in a given field of research, or historical reviews that present the development in a given field of research over time[9]. Our review belongs to the historical category as we have included papers from 1993.

Strategize Search

Database

We reviewed papers from ASEE (American Society of Engineering Education)'s Journal of Engineering Education (JEE) (ISSN 2168-9830), which is a primary publication choice for the US engineering education researchers[10]. Pawley et al.[11] argue that JEE is the flagship and the most highly ranked American journal of the engineering education researcher community and chose it for their gender research review that identifies the dominant themes and patterns in the structure of gender research. JEE is hosted by Wiley and provides an advanced search mechanism, however, we did not find it to be user friendly. Therefore, we identified articles using the Publish or Perish tool and the Google scholar database.

Search Terms

We searched for papers having at least one term for women underrepresentation and at least one term for success. Table 1 shows the underrepresentation and success terms. We developed an initial set of search terms based on literature review. We requested feedback on the search terms from experts in the field and revised them appropriately. Based on the feedback we added "student performance", "dropout", and "drop-out" to the list of success phrases.

Table 1 - Search Terms. (Selected papers have at least one underrepresentation term and one success term).

Underrepresentation terms	gender OR female OR woman OR women OR underrepresented OR minority OR minorities
Success terms	persistence OR retention OR "student success" OR "students' success" OR attrition OR "student performance" OR dropout OR drop-out

Synthesize Papers

Code and quality check

Our search yielded 244 papers published between 1993 and 2016. Out of them, based on abstracts, we found 188 papers to be not relevant i.e. not discussing the success of undergraduate women engineering students in the US. We studied the remaining 57 papers and found 37 of them to be relevant. We coded those 37 papers in an excel sheet (Table 2) and in a word document (Table 3). Author 1 proposed a structure for these tables, which Author 2 and a research scholar reviewed. Furthermore, influenced by Borrego, et al.[12] and Salleh et al.[13], Author 3 conducted a quality check on the papers, which Author 1 reviewed. Unsurprisingly, with JEE, all papers were found to be of high quality. The authors also sought inputs from in-house researchers and external experts to maximize the quality of the research.

Table 2: Coding used for top-level information in excel sheet

Author names	Geography under study (Universities studied)
How many authors are from engineering departments	Method of study (Quantitative or Qualitative)
Departments of the authors	Subject of study (Gender, All underrepresented, intersection such as Hispanic Women
How many authors are from education / other departments	Title
Universities of the authors	Year of publication
Category (Core[1], Periphery, Review)	Quality ranking (High, Medium, Low)
Type (Analysis, Analysis + solutions, and Analysis + Solutions with evidence)	

Table 3: Coding used for detailed information in word document

Title, Authors and Publication year	Solutions presented
Focus and Research questions	Research methods adopted
Data collected /presented	Key conclusions
Frameworks used	Quotes (from other papers)
Analysis	Important references (useful papers referred by the paper)

Synthesis

Patterns

Out of the 37 relevant papers 18 presented solutions, 18 presented only analysis of problems without proposing solutions, and one was a review paper. All but one papers belonged to the core[1] category.

Of the eighteen solution papers, twelve used quantitative methods, five used qualitative methods, and one paper used a mixed-methods approach. Over time, the papers have used advanced statistical techniques, and qualitative or mixed methods. The research appears to be concentrated in a few institutions such as Purdue and is, of late, emanating more from education

[1] The papers with research questions having 'gender success' related terms are classified as core and others are classified as periphery

departments. Further, all the papers limit scope of success to academic; none examine success of graduates once they are in professional positions.

We were ideally looking for papers that tested solutions in an experimental design (with a control or comparison group) and post-solution success measurements (such as retention). Only two papers[14 15] came close to this ideal. However, even they fell short of selecting treatment and control groups randomly.

Influenced by previous systematic reviews, we have summarized the solution papers in Appendix A. We provide author names & publication year, affiliations, research methods used, paper title, category, and pertinent research question(s) of each paper.

Solutions

In this section, we qualitatively analyze the solutions presented in the papers that we studied. We categorized the solutions based on four temporal phases: K12, admission to college, transition to college, and during college (Figure 3). We have further divided the 'during college' phase in three areas; academic, social, and professional integration based on prior work by Lee and Matusovich[16], who undertook a multi-case study of six programs for under-represented students to develop a model for co-curricular support based on Tinto's institutional departure model. The model included integration at academic, social, professional, and university levels. We excluded university integration as we did not find any solution in our review in that category.

We summarise the solutions in Appendix b and describe them in the forthcoming sections based on the four phases. We include solutions that have emanated from empirical studies and that specifically benefit undergraduate women students studying in the US. We exclude future research directions, which also may be solutions. Some authors analyzed problems and have recommended solutions based on their analysis and literature, which we have included.

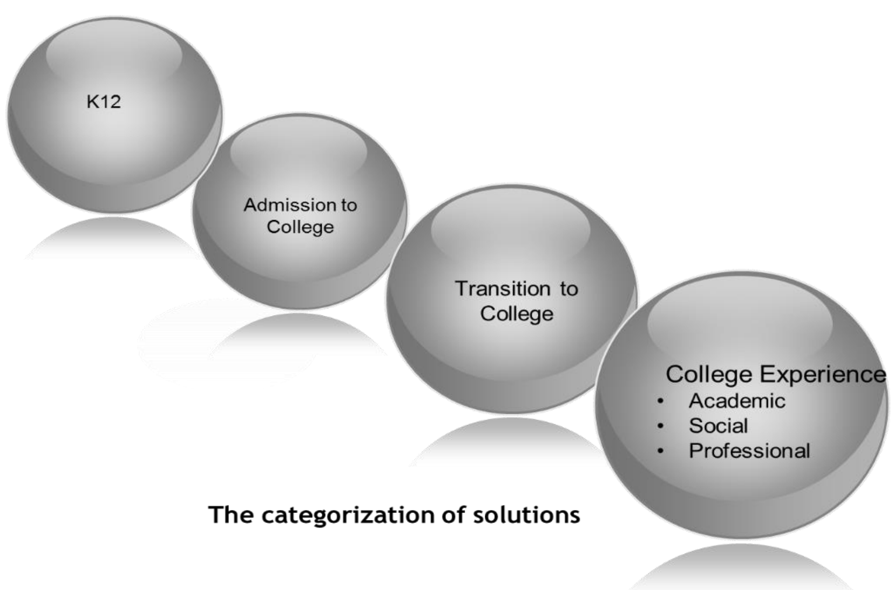

Figure 3: The categorization of solutions in four temporal phases

K12

There were three solutions that focused on the K-12 phase: 1) adding engineering related contents to K-12 syllabus, 2) mentoring proactively, and 3) focusing on agency.

Cohen and Deterding[17] propose revising K-12 syllabi by offering engineering as an elective or incorporating special units on engineering applications into existing mathematics and science courses. They further add that these types of curricular reforms are already being implemented in some middle schools, are providing opportunities for students to see real life applications of theoretical knowledge acquired in mathematics, physics and other subjects, and are exposing to opportunities in the engineering professions. Godwin et al.[18] suggest implementing the NGSS (Next Generation Science Standards), which explicitly includes practices and core ideas from engineering and technology to develop appropriate identities of students, which can guide them in choosing and performing in their engineering careers.

Martin et al. suggest mentoring students pro-actively[19]. Murphy et al. underline the need for proactive recruitment of students in their high-schools. That includes the department chairs personally inviting promising high school students to consider their department majors, and faculty and students teams giving presentations about the department to high school classes[20]. Martin et al.[19], based on their study on Hispanic women students, point out that successful first-generation college students and children of immigrants, who are succeeding as engineering majors may be particularly powerful role models and agents of social capital (resources embedded in a social structure that are accessed or mobilized in purposive actions). Samuelson and Litzler [21] highlight the need of developing navigational capital (understanding how to successfully navigate educational institutions with dominant cultural norms). Felder [22] appeals peers, teachers and parents not to discourage women from joining engineering courses.

Godwin et al.[18] argue that agency (how students perceive their empowerment to bring about changes) is an important characteristic of successful women students and suggest emphasizing the utility of science and engineering in bringing about meaningful changes in the world to develop the agency.

Admission

Three solutions focused on the admissions phase: 1) changing admissions policy / criteria, 2) increasing outreach and presenting diversity in colleges, and 3) involving family in the admissions process.

Holloway et al.[15] have found that motivation, propensity toward deep learning, and self-perception of leadership ability better predict success of women engineering students (unlike math standardized test scores and previous coursework in math and science for men students) and have shown that an admission process that includes predictors for both genders can increase recruitment of women students. Their experiment of changing admission criteria as above, at a mid-western university, resulted in an increase in female admissions by 19% over the previous year (while applicants increased by only 11%), and an increase in the female enrollment to 26%, from earlier year’s 21%.

Cohen and Deterding[17] have found that the gender disparity is a recruitment issue, which requires increasing outreach within institutions of higher education and across institutions (into two-year colleges, middle and high schools). Industrial Engineering at Oklahoma University has demonstrated that proactive and informative attention, and ensuring that women faculty are visible in different activities can attract more women students[20,23]. The departments can also encourage the current students to work as departmental emissaries in their universities and increase the outreach[20].

Trenor[24] recommend that programs for successful recruitment and retention of female students consider the important roles that parents play in the selection and persistence of those students. Samuelson and Litzler[21] suggest strengthening familial capital by bringing families to campus and providing them with information on how best to support students. Martin et al.[19] also emphasize the need for improving parental education regarding the processes for university admission, financial aid, expected engineering course load, and long-term benefits of earning an engineering degree. They specifically suggest considering language barriers while designing parents' events.

Transition

The transition solutions focused on 1) making curricular changes and 2) developing social capital in community colleges for engineering.

Hoit and Ohland showed, with statistically-significant evidence, that presenting the real engineering content, in the first-year itself, helps retain women students[14]. They introduced the introduction to engineering course in a laboratory format, where they employed active learning with smaller class sizes, and rotated students through laboratories in each undergraduate engineering department. They studied three different cohorts, wherein students could choose either the new laboratory format, which 42 women students did; or traditional lecture based format, which 92 women students did. The authors found women retention (remaining in the program till the third year of study) in the lecture-based format was at 16%, and that in the laboratory format was at 52%. Brainard and Carlin suggest including core courses in sophomore instead of junior year[25] to ease students' transition into engineering.

Many underrepresented students transition from community colleges, which need to catalyze development of social capital required for engineering[19].

College Experience – Academic and Social Integration

We divide the academic and social integration solutions in two areas; instructional environment and contextual support.

Instructional Environment

Four solutions covered the college instructional environment. They are, 1) removing instructional bias towards women, 2) using student-centered pedagogical methods that involve more interactions with faculty and peers, 3) having curriculum that supports diversity, and 4) developing identity and agency beliefs.

For women to be successful in engineering, instructional environments must remove biases towards them. To do so, Felder et al.[22] support several measures, such as being careful not to use gender-sensitive material and language, avoiding routine placement of women in stereotypical ("secretarial") roles in group work, and seeking equal involvement of all students, and recognizing that women may tend to be less assertive than men in volunteering responses or asking questions in class, as suggested by Henes. Bell et al. [26] support measures such as not making seemingly helpful comments that imply women are not as competent as men and not disparaging women in general, women's intellectual abilities, or women's professional potential. They also add not using sexist humor as a classroom device and positive behaviors such as using terminologies that include both men and women, calling directly on women students as well as men students in class, and asking women and men qualitatively similar questions (critical and factual questions). Samuelson and Litzler [21] suggest creating courses and workshops focused on stereotype threat so that students can develop transformational resistance (involves behavior that demonstrates both a critique of oppression and a desire for social justice). Foor et al.[20] recommend faculty to pay attention to "us" and "them" classroom dynamics that are established as a result of "capital differences" among diverse students and to be aware that students with average grades can also excel as engineers. In general, Foor et al.[27] insist that faculty must make under-represented students feel "more welcome" in engineering colleges

Since women often benefit more by working in groups, Felder et al.[22] suggest the use of cooperative learning. They also warn about possibilities of women's contribution getting undermined in the mixed gender groups and suggest structuring groups that provide equal benefits to men and women students. Johnson and Sheppard[28] point out that programs that permit one-on-one interaction with faculty members help women and recommend engineering faculty create environment that welcome, include, and support the participation of all students. They further suggest undergraduate students taking up research assignments to increase their interactions with faculty. The research experience can pave the way for higher studies, which may lead those students to academic careers addressing the shortage of women mentors and role models required for women engineering students. Raelin et al.[29] recommend instructional style that is more experiential than rote. Ro and Knight[30] found that a greater frequency of student-centered teaching led to greater self-reported design skills for women students; and greater curricular emphases on professional skills such as teamwork and communication abilities led to greater self-reported leadership skills and design skills for women students. Greater curricular emphases on core engineering also helps women students to develop better leadership skills but on much lesser scale than men students. This cross-sectional study included close to five thousand students from sophomore, junior and senior years from 31 four-year colleges and universities in seven engineering disciplines that accounted for over 70% of all baccalaureate engineering degrees awarded in 2007 in the US. Godwin et al.[18] recommend that engineering educators show the utility of science and engineering through student-oriented classroom discussions or demonstrations and real-world applications of engineering and science.

Johnson and Sheppard[28] second Busch-Vishniac and Jaroz's proposition to revise engineering curriculum that promotes diversity, which can change student demographics.

Godwin et al.[18] also put forth the need of developing identity by recognizing students for their good performances, and developing agency beliefs by representing engineering not only as a technical discipline centered on math, equations, systems, and computing, but also as a discipline that has huge social relevance.

Contextual Support

Seven solutions focused on the contextual support, 1) supporting financially low-income women students, 2) providing women mentors and role models, 3) creating an atmosphere, where women students feel like faculty care about them, 4) involving family in the education process, 5) supporting formal support structures such as SWE (Society for Women Engineers) and professional clubs, 6) providing diverse ethnic environment, and 7) executing departmental level initiatives. For Raelin et al. [29], contextual support includes a number of mechanisms such as providing financial aid, mentoring, facilitating more students to live on campus, and developing professional clubs and living-learning communities. They found women retention to increase from 21% to 47% as the contextual support changes from low to high level, and the men retention, with the same change, to increase mildly from 30% to 33%. The three-year longitudinal study covered four institutes with over 1,600 students responding to the survey after the freshmen year, which reduced to 700 responding to the survey after the third year.

Johnson and Sheppard[28], and Trenor et al.[24] second Raelin et al. on providing strong financial support for low-income women students, who tend to come from underrepresented ethnic minorities. Ethnic minority groups represent a higher proportion of woman engineering students (23.5% for black and 20.7% for Hispanics as compared to 18.4% for whites),[31], and financial support may increase those proportions, further.

Felder et al.[22] and Johnson and Sheppard[28] support Raelin et al. in providing women engineering students with women role models and mentors, and point out the critical need of addressing the shortage of women faculty members. Until the shortage is addressed, Felder et al.[22] suggest that colleges can rely on peer mentoring i.e. mentoring by senior women students.

Faculty can play a pivotal role in the success of women students. While Felder et al.[22] point out the need to educate professors and academic advisors about the problems and needs of women students, Murphy et al.[20] advocate faculty exhibiting behaviors that women students perceive as a high level of care for them as individuals. Such efforts would help the students to develop the required social capital as espoused by Martin et al.[19]. Foor et al.[20] advocate that engineering educators be trained in critical cultural theory and be aware that cultures are engineered by people. The educators, they point out, have to change the dominant culture to be more inclusive of diversity, especially of individual diversity (i.e. breadth of experience of an individual) of both faculty and students.

Martin et al.[19] support the need for involving family in the educational process and developing familial capital as articulated by Samuelson and Litzler[21]. Martin et al.[19] highlight the need of improving parental education regarding financial aid options, expected engineering course load, and long-term benefits of earning an engineering degree, and emphasize designing events and activities for parents by taking care of their language preferences. Samuelson and

Litzler[21] suggest family engagement programs to encourage familial capital by bringing families to campus and providing them with information on how best to support students.

Having formal structures such as SWE (Society for Women Engineers) and professional clubs can go a long way in providing contextual support to women students as found by many researchers,[19,22,28,30] thereby helping them develop social capital[19]. Felder et al.[22] believe that such organizations can provide career guidance and emotional support to women students, and provide a natural forum for successful women engineers to return to campus and provide a realistic and positive picture of engineering as a career for women. Ro and Knight[30] claim that women students, who participated in non-engineering clubs or activities reported greater improvement in fundamental skills, contextual competence, and communication skills than men. Those women students, who participated in engineering clubs for women or underrepresented minorities reported greater improvement in communication skills than men, although the improvement was lesser than for those who participated in non-engineering clubs or activities. Johnson and Sheppard[28] found a mixed impact of such organizations on retention rates of underrepresented students, but found evidence that the most successful programs provide strong financial support, create a successful learning environment by ensuring access to role models, faculty mentorship, and organizing peer support. Martin et al.[19] recommend supporting organizations of underrepresented students, which can help them in evolving peer networks and resulting in development of social capital of those students. All this amounts to creating successful and supportive learning environment as articulated by many authors [28] [19,20,29].

Trenor et al.[24] have further found that diverse ethnic environments (where no group is singled out as minority) help in achieving a highly supportive educational system for students of all ethnicities, which matters more for women students.

The contextual support can also be provided by individual departments, by presenting diversity, collegiality, and multifaceted professional image that is relevant to students' lives. The departments having diverse faculty and staff, who respect their colleagues' abilities and work together toward a common departmental goal catalyzes better contextual support. Also, the departments that offer diverse experiences and pave the way for jobs that are "pro-social" or humanistic, provide comprehensive type of life, and value competence in several areas simultaneously are liked by women students[20,23].

College Experience – Professional Integration

There is not much work done in the professional integration area. All students look forward to embarking on their professional careers and women students are no exceptions, but they have specific requirements that need to be addressed. Women students want to have successful careers as well as want to fulfill their family and, especially child rearing responsibilities. Women can benefit from having discussions on topics such as dual-career families, flexible work schedules, and career ladders with practicing engineers (both men and women) and placement officials to resolve potential work/family conflicts[32].

Measurements

Wrong measures generate wrong solutions, and right measures generate right solutions. In that context, Ohland et al.[33], establish that trajectories of persistence are gendered and racialized, and point out that the common methods of studying persistence based on overall averages only represent the behavior of the majority, specifically the white, male population. Therefore, they suggest studying data disaggregated by gender and race. They found that measuring six-year graduation, unlike eight-semester persistence, removes measurement biases.

Conclusion

The United States is not producing enough STEM workers, which jeopardizes its leadership position in the contemporary innovation economy[34]. It is also alarming that these key fields, especially engineering, have huge underrepresentation of women. While women constitute 56% of college graduates[35], the number plummets to around 20%, when it comes to engineering[36]. That motivated us to carry out a systematic review of literature on improving success of women engineering students.

We found the solution space for improving success of women students in engineering in the US focuses on recruitment in K-12, community colleges, and regular colleges; and better academic and social integration with the help of refined instructional environment and superior contextual support to women students.

While the problem of lower numbers of women graduates is clear to all, there are different views about appropriate solutions. Some argue that any student with the will to excel, regardless of race or gender, will succeed if exposed to good teaching practices[37]. Others argue that treating all students as equals is not appropriate, as the treatment may have different effects on different groups[33]. We believe that the truth may lie somewhere in between. While some techniques and practices may influence populations differently, others may not; and implementation will play a significant role in the results. In that context, we agree with Reichert and Absher[37] when they say that more than the details of programs, the care with which they are executed matters. Since the solutions are mainly owned by faculty, we believe that they must undergo appropriate development programs.

We studied 37 relevant JEE papers from 1993 to 2016. Of them, only 18 provided solutions, two of them with evidence of success. This lack of empirical data may limit adoption of the solutions. Moreover, results may depend on the context of the study (e.g., type of college, geography)[28], which requires practitioners taking the source context into account before adopting reported solutions. Further, all papers limit their definition of success to academic, rather than professional success. We hope that the critical need for workforce diversity will drive future research to include the professional success.

The term ‘student success’ appears to be in the process of getting formalized, which may have resulted in our search missing some papers. Like Pawley et al.[11] our systematic review was limited to JEE – the premier US journal of engineering education. To more deeply understand all the challenges and possible solutions, a meta-review that includes other journals such as IJEE

(International Journal of Engineering Education), AEE (Advances in Engineering Education) and JWMSE (Journal of Women, Minorities, in Science and Engineering) from the US perspectives, and EJEE (European Journal of Engineering Education) and AAEE (Australasian Association for Engineering Education) from global perspectives is warranted. However, the solutions reported in the paper can help in catalyzing the success of women engineering students and can provide foundational support towards more comprehensive research.

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Appendix A: The papers studied

Author Names & Year	Author Affiliation	Method	Title	Research question or focus
Felder, et al (1995)	NC State	Quant	A longitudinal study of engineering student performance and retention. III. Gender differences in student performance and attitudes	What are gender differences in the students' academic performance and persistence in chemical engineering, and attitudes toward their education and themselves?
*Hoit and Ohland (1998)	University of Florida	Quant	The impact of a discipline-based introduction to engineering course on improving retention	What is the impact of a discipline-based introduction to engineering course on improving retention of different groups?
Brainard and Carlin (1998)	University of Washington	Mix	A six-year longitudinal study of undergraduate women in engineering and science	Examine factors affecting retention of women in science and engineering; and to evaluate the effectiveness of WIE's programs?
Hawks and Spade (1998)	Bentley and Lehigh	Quant	Women and men engineering students: Anticipation of family and work roles	What are the anticipated role conflicts of women and men engineering students in their careers?
Bell et al. (2003)	Virginia Tech, Waterloo	Quant	Stereotype threat and women's performance in engineering	What is the effect of stereotype threats on women's performance
Johnson and Sheppard (2004)	Stanford	Quant	Relationships between engineering student and faculty demographics and stakeholders working to affect change	What is the progress of the high school class through the engineering pipeline and beyond, specifically focusing on women and underrepresented minority students?
Foor et al. (2007)	Oklahoma	Qual	" I wish that I belonged more in this whole engineering group:" Achieving individual diversity	What is the impact of STEM culture on individual diversity?
Murphy et al. (2007)	U Oklahoma and some more	Mix	Achieving parity of the sexes at the undergraduate level: A study of success	Study women migration to engineering majors and retention.
Trenor et al. (2008)	Clemson and U of Houston	Qual	The relations of ethnicity to woman engineering students' educational experiences and college and career plans in an ethnically diverse learning environment	What are the experiences of women students in an ethnically diverse learning environment?

Walden, and Foor (2008)	U Oklahoma	Quant	"What's to keep you from dropping out?" Student Immigration into and within Engineering	What impact did the decision of students to relocate to IE have on the achievement of sex parity in fall 2001 for industrial engineering at Oklahoma University?
Cohen, and Deterding (2009)	Harvard, non-university	Quant	Widening the net: National estimates of gender disparities in engineering	What are the causes behind the severe underrepresentation of women in engineering?
Ohland et al. (2011)	Purdue, San Diego, Rose Hulman	Quant	Race, gender, and measures of success in engineering education	Which measures of success are justifiable to women and minorities?
Martin et al. (2013)	Clemson, Virginia, Houston	Quant	The role of social capital in the experiences of Hispanic women engineering majors	For Hispanic women whose parents have limited educational attainment, how they manage social capital?
Raelin et al. (2014)	Northeastern, RIT, Wyoming, Virginia Tech	Quant	The gendered effect of cooperative education, contextual support, and self-efficacy on undergraduate retention	What is the effect on retention of demographic characteristics, cooperative education, contextual support, and three dimensions of self-efficacy?
*Holloway et al. (2014)	Purdue, Texas A & M, Ohio, Northwestern	Qual	Research-informed policy change: A retrospective on engineering admissions	Is there statistically significant evidence of gender bias in admission process of engineering programs?
Samuelson and Litzler (2016)	U of Washington	Quant	Community cultural wealth: An assets-based approach to persistence of engineering students of color	What differences in community cultural wealth emerged at the intersection of race/ethnicity and gender?
Ro and Knight (2016)	Virginia Tech, Bowling Green State	Quant	Gender differences in learning outcomes from the college experiences of engineering students	How do curricular emphases, instructional approaches, and participation in co-curricular activities differently affect engineering learning outcomes by gender?
Godwin et al. (2016)	Purdue, Florida, Texas A & M	Quant	Identity, critical agency, and engineering: An affective model for predicting engineering as a career choice	Students' beliefs about the ability of science to improve the world predict choice of engineering as a career and whether these beliefs differ by gender.

*These papers have provided evidences to their solutions.

Appendix B: The solutions presented by the papers

K-12	
1) adding engineering related contents to K-12 syllabus.	• Cohen and Deterding (2009), Widening the net: National estimates of gender disparities in engineering • Godwin (2016), Identity, Critical Agency, and Engineering: An Affective Model for Predicting Engineering as a Career Choice
2) mentoring proactively including building social and navigational capital.	• Martin et al. (2013), The role of social capital in the experiences of Hispanic women engineering majors. • TJ Murphy et al. (2007), Achieving parity of the sexes at the undergraduate level: A study of success • Samuelson and Litzler (2016), Community Cultural Wealth: An Assets-Based Approach to Persistence of Engineering Students of Color • Felder et al. (1995), A Longitudinal Study of Engineering Student Performance and Retention. III. Gender Differences in Student Performance and Attitudes
3) focusing on agency (how students perceive their empowerment to bring about changes).	• Godwin (2016), Identity, Critical Agency, and Engineering: An Affective Model for Predicting Engineering as a Career Choice
Admission	
1) Changing admissions policy / criteria.	• Holloway (2014), Research-Informed Policy Change: A Retrospective on Engineering Admissions
2) increasing outreach and presenting diversity in colleges.	• Cohen and Deterding (2009), Widening the net: National estimates of gender disparities in engineering • TJ Murphy et al. (2007), Achieving parity of the sexes at the undergraduate level: A study of success

	• Walden and Foor (2008), "What's to keep you from dropping out?" Student Immigration into and within Engineering
3) Involving family in the admissions process.	• Trenor at al. (2008), The Relations of Ethnicity to Woman Engineering Students' Educational Experiences and College and Career Plans in an Ethnically Diverse Learning Environment • Martin et al. (2013), The role of social capital in the experiences of Hispanic women engineering majors. • Samuelson and Litzler (2016), Community Cultural Wealth: An Assets-Based Approach to Persistence of Engineering Students of Color
Transition	
1) making curricular changes.	• Hoit et al. (1998), The Impact of a Discipline-Based Introduction to Engineering Course on Improving Retention • Brainard et al. (1998), A six-year longitudinal study of undergraduate women in engineering and science
2) developing social capital in community colleges for engineering.	• Martin et al. (2013), The role of social capital in the experiences of Hispanic women engineering majors.
College Experience – Academic and Social Integration: Instructional Environment	
1) removing instructional bias towards women.	• Felder et al. (1995), A Longitudinal Study of Engineering Student Performance and Retention. III. Gender Differences in Student Performance and Attitudes • Bell et al. (2003), Stereotype threat and women's performance in engineering • Samuelson and Litzler (2016), Community Cultural Wealth: An Assets-Based Approach to Persistence of Engineering Students of Color • Foor et al. (2007), "I wish that I belonged more in this whole engineering group:" Achieving individual diversity
2) using student-centered pedagogical methods that involve more interactions with faculty and peers.	• Felder et al. (1995), A Longitudinal Study of Engineering Student Performance and Retention. III. Gender Differences in Student Performance and Attitudes • Johnson et al. (2004), 'Relationships between engineering student and faculty demographics and stakeholders working to affect change • Raelin et al. (2014), The gendered effect of cooperative education, contextual support, and self-efficacy on undergraduate retention

	• Ro and Knight (2016), Gender Differences in Learning Outcomes from the College Experiences of Engineering Students • Godwin (2016), Identity, Critical Agency, and Engineering: An Affective Model for Predicting Engineering as a Career Choice
3) having curriculum that supports diversity.	• Johnson et al. (2004), 'Relationships between engineering student and faculty demographics and stakeholders working to affect change
4) developing identity and agency beliefs.	• Godwin (2016), Identity, Critical Agency, and Engineering: An Affective Model for Predicting Engineering as a Career Choice
College Experience – Academic and Social Integration: Contextual Support	
1) supporting financially low-income women students.	• Johnson et al. (2004), 'Relationships between engineering student and faculty demographics and stakeholders working to affect change • Trenor at al. (2008), The Relations of Ethnicity to Woman Engineering Students' Educational Experiences and College and Career Plans in an Ethnically Diverse Learning Environment
2) providing women mentors and role models.	• Felder et al. (1995), A Longitudinal Study of Engineering Student Performance and Retention. III. Gender Differences in Student Performance and Attitudes • Johnson et al. (2004), 'Relationships between engineering student and faculty demographics and stakeholders working to affect change
3) creating an atmosphere, where women students feel like faculty care about them.	• Felder et al. (1995), A Longitudinal Study of Engineering Student Performance and Retention. III. Gender Differences in Student Performance and Attitudes • Martin et al. (2013), The role of social capital in the experiences of Hispanic women engineering majors • TJ Murphy et al. (2007), Achieving parity of the sexes at the undergraduate level: A study of success • Foor et al. (2007), "I wish that I belonged more in this whole engineering group:" Achieving individual diversity
4) involving family in the education process.	• Martin et al. (2013), The role of social capital in the experiences of Hispanic women engineering majors

	• Samuelson and Litzler (2016), Community Cultural Wealth: An Assets-Based Approach to Persistence of Engineering Students of Color
5) supporting formal support structures such as SWE (Society for Women Engineers) and professional clubs.	• Felder et al. (1995), A Longitudinal Study of Engineering Student Performance and Retention. III. Gender Differences in Student Performance and Attitudes • Ro and knight (2016), Gender Differences in Learning Outcomes from the College Experiences of Engineering Students • Johnson et al. (2004), 'Relationships between engineering student and faculty demographics and stakeholders working to affect change • Martin et al. (2013), The role of social capital in the experiences of Hispanic women engineering majors. • Raelin et al. (2014), The gendered effect of cooperative education, contextual support, and self-efficacy on undergraduate retention • TJ Murphy et al. (2007), Achieving parity of the sexes at the undergraduate level: A study of success
6) providing diverse ethnic environment.	• Trenor at al. (2008), The Relations of Ethnicity to Woman Engineering Students' Educational Experiences and College and Career Plans in an Ethnically Diverse Learning Environment
7) executing departmental level initiatives.	• TJ Murphy et al. (2007), Achieving parity of the sexes at the undergraduate level: A study of success • Walden and Foor (2008), "What's to keep you from dropping out?" Student Immigration into and within Engineering
College Experience – Professional Integration	
1) organize discussions on topics such as dual-career families, flexible work schedules, and career ladders with practicing engineers (both men and women) and placement officials to resolve potential work/family conflicts.	• Hawks and Spade (1998), Women and men engineering students: Anticipation of family and work roles

	Measurements
1) study data disaggregated by gender and race, use actual six-year graduation data instead of any indirect persistence data	• Ohland et al. (2011), Race, gender, and measures of success in engineering education.