AC 2010-1195: DESIGN OF THE LEARNING ENVIRONMENT FOR INCLUSIVITY: A REVIEW OF THE LITERATURE

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Design of the Learning Environment for Inclusivity: A Review of the Literature

Abstract

Retention, especially of under-represented populations through the first year university, is an on-going concern in engineering programs. While this is a very complex issue, one of the aspects of retention that is being studied is the barriers to inclusion that some students feel when they enter university. There are many programs aimed at helping freshman acclimatize to the university environment and the issue of inclusivity is becoming more pronounced as we strive to increase and then maintain the diversity of our student population in engineering programs.

There are many ways of approaching issues of student success toward a goal of improving diversity. However, the literature on this subject is highly fragmented. There is a cluster of work on students with learning disabilities, which is found primarily in the equity and disability literature. Then there is a considerable cluster of work on first generation students and minorities and the cultural issues that these students may face when entering university. And in the engineering education literature there is some work on minority student success strategies and a substantial amount of work on improving the retention of women in engineering programs. A fraction of this literature across all of these fields considers the barriers to inclusion that students may encounter in their engineering studies and, in particular, how the design of the learning environment impacts retention. The work in the area of design for retention comes mainly from literature in the field of higher education studies.

In this paper we review the research on this subject, both in the engineering education literature and literature from other disciplines. From this review we have created a framework for understanding different approaches that have been taken to making the learning environment more inclusive for diverse student populations. This research identifies approaches that may be effective and transferable, and a number of open questions that should be investigated further.

Introduction

A look at current engineering classrooms shows how the demographic composition has diversified, especially in recent years. Most retention programs are aimed at freshman because of the vulnerability of this population, so questions of inclusivity and retention are particularly applicable to freshman programs. With constant change in the learner base, coupled with increasing diversity, one begins to question how engineering education should evolve to meet the needs of the next generation of students, and how this evolution affects the students.

Students with learning disabilities (physical and mental), minority students who are affected by the cultural undertones of contextualization, and gender issues are three major areas of diversity that are affected by inclusivity in the classroom. This paper attempts to review the literature on the subject of inclusivity with respect to these issues, within the context of first year post-secondary education, to create a practical framework that unites the different approaches into an up-to-date resource that is relevant for engineering.

The Online Ethics Center at the National Academy of Engineering[1] has a collection of over 50 abstracts that address teaching to diversity in engineering. Minority retention rates in post-secondary education, for instance, is a topic that also falls in this category. The 2008 annual report by the National Action Council for Minorities in Engineering[2] reviews the statistics on minority engineering students, and practicing engineers. Similar statistics exist for women in engineering.[3,4] The statistics clearly show that women and minorities are often under-represented in engineering, and there are programs at many universities related to recruitment and retention that attempt to address this issue.

Although many programs exist, it is unclear what makes a retention program effective. It would be inappropriate to simply assume that a specific effective program at one institution could be successfully replicated at a very different type of institution. However, it would be useful to know if there are particular types of programs or approaches that have been successfully implemented across a variety of institutions. We might be able to conclude that there are proven methods that can be adapted to a specific institution to work in a particular context. Furthermore, by looking at the literature on inclusivity across diversity (gender, minority, and learning disabilities) we can see if there are commonalities in effective approaches that can be leveraged. Applying such strategies in an engineering context also has some unique challenges that need to be addressed.

The literature that was reviewed for this project covered three major populations: women, minorities, and people with learning disabilities. While it is possible to find hundreds of citations for each of these categories, references were chosen for breadth. For this reason some of the references are review articles that draw together literature from a large number of primary sources, but virtually all of the literature focuses on one population or another, or on the learning environment in general. Our purpose here is to view this literature altogether to identify commonalities that are relevant and useable for engineering, thus creating a framework for understanding effective approaches to inclusivity that can operate across a variety of populations.

Students with Learning Disabilities

Learning Disabilities (LD) are defined as "the conditions giving rise to a difficulty in acquiring knowledge and skills, especially in comparison with the norm for one's peer group, typically because of a mental disability or cognitive disorder."[5] A number of recent publications look at the prevalence of learning disabilities in the classroom. These include studies ranging from the identification of students with visual impairment, autism,[6] and auditory processing disorders.[7] A review of the results from these sources indicates an increasing prevalence of children with LD which will translate into an increase in engineering students with LD. Further, research exists that suggests that disabilities have no effect on an individual's intelligence, and therefore students in this population ought to have an equal opportunity to be successful in a learning institution. The studies generally conclude that increased inclusivity in the learning environment is beneficial.

The sources reviewed for this project are from the engineering, equity, and disability literature, and pertain to a wide variety of identified disabilities. A particularly comprehensive resource,

Brinckerhoff et al.[8] has over 900 references that discuss approaches that identify and address LD issues. It includes an analysis of the LD population, the dynamic process of providing accommodation, as well as tools for performing future work in the field. Scotch[9] has reviewed the issues of preexisting bias, the presence of dominant tendencies in the workplace, disabling environments, assumptions of incapacity, and the culture of disability policy. A more recent article by Kavale et al.[10] argues that the traditional definition of a learning disability "has remained static for 40 years, creating a schism between theory and practice." Particularly, the authors suggest that the definition of LD ought to be updated to a more rigorous construct of physical as well as mental disability, including emotional disturbances of environmental, cultural or economic disadvantage. Similarly, Williams et al.[11] recently published the results of their research on learning disabilities and how the sharing of information can influence particular outcomes. Their article concluded that sharing knowledge about student behaviors creates an increasingly personalized relationship with the learning population.

One route to addressing the issue of disabling learning environments is universal instructional design (UID), also called universal design in education. Bowe[12] and Burgstahler et al.[13] review the history of this approach and explore the principles behind it. The UID principles are aimed at changing the learning environment to reduce the barriers to learning for a broad range of students, while enhancing the environment for all students. The principles, drawn from universal design in architecture, are intuitively appealing. However, McGuire et al.[14] have pointed out that this approach has not yet been rigorously tested.

Research on methods for addressing issues of LD has increased over time. Again, although there are many publications in this area, only the most recent and summative examples are chosen to discuss here. Research published in late 2009 considers the effects of computer-assisted instruction on the mathematics performance of students with learning disabilities.[15,16] Although the instructors were generally willing to provide additional instructional and adapted materials to assist LD students, increased class sizes and lack of additional support structure made this approach difficult. Seo and Bryant[17] analyzed 11 existing studies that compared computer assisted instruction (CAI) to face-to-face teaching. Although there was no consensus on whether CAI is advantageous per se, the authors were able to identify several key issues which need to be addressed before CAI can be realistically compared with traditional teaching practice. They suggest that CAI should be based on a valid learning theory (i.e. based on cognitive and constructivist models rather than behavioral) and should incorporate critical instruction features (such as feedback, etc). The validity of using CAI to assist LD students still needs to be studied further. The Seo and Bryant study is important because "e-learning" is gaining increased attention as a method of assisting students with learning disabilities. Another example is Todd's work which considers several recent studies that aim to promote e-learning as a tool for assistive education.[18] LoPresti et al.[19] review assistive technologies currently being explored to reduce accessibility barriers, and provide improved quality of life.

The literature shows that learning disabilities can affect both student success and inclusivity. In general, the literature suggests that increasing interaction between the instructor and the student is effective, and when that becomes difficult, methods such as e-learning that supplement traditional learning can be useful. However, e-learning is not universally effective and to be effective it must be understood well by both the instructor and the student, and it must

incorporate key elements of pedagogy. The advantages and disadvantages of a student-centered approach versus changing the institutional environment as a whole are summarized in Table 1.

The literature is now clear that bright students with learning disabilities also have much to contribute to the engineering profession. Most of our current practice in terms of retaining these students is based on finding appropriate individualized accommodations, but increasingly the literature points to changing teaching practice as a means of creating inclusivity. The literature on learning disability has also begun to point to a wider variety of factors such as economic and cultural differences (e.g. Kavale et al.[10]) that should be accounted for in the learning environment if we intend to create inclusivity.

Minorities and First Generation Students: Cultural Issues

When students first enter university there is a period of adjustment when they must transition from the environment and learning skills they were accustomed to in high school, to a new environment with new demands. This period of transition, or feeling they are not yet successfully adjusted, can be especially acute for first generation and minority students. First generation students are people who are the first in their family to go to college. Admission decisions are generally based on grades, extracurricular activities, capacity to communicate in the language of instruction etc. However, these attributes do not necessarily measure how easily a student will fit into the learning environment, especially if the new learning environment and culture of the institution are very different than what they have experienced before. Nor do we want to exclude students who come from diverse backgrounds because they may have difficulty adjusting. This would have significant negative consequences for the institution, the learning environment, and the engineering profession.

Traditionally there has been an over-representation (relative to the general population) of white men in engineering in North America. This is a simplistic statement because it ignores hidden diversity. However, many aspects of current learning environments in engineering implicitly assume this simplistic homogeneity. As a result, students from diverse backgrounds may have difficulty adjusting to the institutional environment. This may be felt both inside and outside the classroom. We will focus here on the learning environment where cultural differences can result in unnecessary barriers to learning, for example, making meaning of the contextualization used in engineering applications. Eventually this can affect student success and retention because it leads to a disconnect between the learner and the material which can compromise grades and lead to a sense of alienation.

The cluster of work in this area is extensive, and is spread over many disciplines. For this reason, recent work, and that most closely-related to inclusivity in the first year engineering classroom, will be examined preferentially.

In a recent article Tapia[20] argues that diversity requires attention to the student and institutional commitment. He gives examples of exemplary programs at various “top-tier” universities that support inclusive environments for minority students, and contends that a supportive institutional environment benefits everyone. Malone and Barabino[21] considered such environments as they examined the role of environment in identity-formation. They also performed a comprehensive

analysis of narrations of race in science, technology, engineering, and math (STEM) settings. Their work identifies themes of invisibility and lack of recognition, exclusivity, racialization, and issues of integration of identity. In general, their work pulls together research from various sources, including existing literature and primary research studies.

Understanding the relationship between racial difference and minority inequality is complex. Trytten et al.[22] for example, contend that racial inequality can exist in spite of over-representation. They point to the example of Asian American students in engineering in North America. Specifically, they argue that over-representation "does not remove the racially-based stereotyping and discrimination in our society," and hence minority status. In their work, they describe five approaches for making engineering institutions more equitable, including: creating a support system for all minority groups; educating faculty and students about stereotyping; and remaining vigilant for possible issues including instances of discrimination not reported to the institution. Generally, they claim that minority students may require additional support to facilitate inclusivity, whether they are members of an over-represented or under-represented minority. This article exemplifies a message that is repeated in other sources: that while students from a particular background may face similar obstacles, we need to be careful not to stereotype, but instead to consider how diversity, both visible and invisible, can result in a disconnect between the learner and the learning environment. There are a variety of valuable recent articles in this field for further reading that are directly applicability to first-year engineering.[23,24, 25]

In terms of creating a framework for addressing the needs of culturally-diverse students, we have identified several underlying trends in the literature. First, minority students (cultural, racial, etc.) are subject to unique barriers to learning that "traditional" engineering students do not have to face. Second, the probability of minority student success depends on the degree to which the institution is able to develop and support an inclusive environment. Further, students from over-represented minorities and those with hidden diversity may encounter some of the same barriers to accessibility. Several approaches to mitigating these learning barriers were also examined in the literature including increased resources and counseling, recognition of achievements, and peer/faculty support-groups. Effectively, these add up to a student-centered approach that decreases a sense of alienation. One of the significant current trends is an emphasis on community building to achieve a sense of inclusion. A key recommendation for the in-class engineering learning environment is that contextualization of knowledge should take into account differences in the environmental, cultural, and economic backgrounds of students. The advantages and disadvantages of a student centered approach versus changing the institutional environment as a whole for addressing the needs of first-generation and minority students are summarized in Table 2.

Improving Retention of Women in Engineering Education

There a huge body of literature in the field of gender differences in education, and a portion of this analyzes methods for improving the retention rate of women in engineering education. The number of women entering engineering has risen, but has not risen steadily, and has been out-paced by female representation in other professional fields. Some research suggests that recruitment into engineering is the primary issue, as opposed to retention.[26] However, other

research suggests that women continue to experience a sense of exclusion in the engineering environment which may feedback and influence decisions that are made by the next generation of students. This has been an on-going issue in engineering education, and the consensus is that this is a complex issue that will require a societal as well as institutional evolution.

There are some excellent recent articles in this area that pertain to engineering education. Buchmann[27] identifies areas where women lead and trail men in higher education. Essentially an up-to-date literature review of women in higher education, Buchmann also investigated the correlation between gender differences and student success rates. Leicht-Scholten et al.[28] describe how the international community is fostering gender inclusivity in engineering education. And Garforth and Kerr[29] analyze the issues of gender differences in science, technology, and engineering using a Foucauldian approach. This approach seeks to identify a feminine perspective by considering how women describe their interaction with the institution. They advocate incorporating this perspective into the academy instead of trying to acclimatize women into a preexisting environment. Gender disparity is also analyzed in a cluster of articles summarized in the summer 2009 National Women's Studies Association Journal.[30] The consensus is that inclusivity in science requires approaches that can be "varied and thus appeal to a wide variety of learners, and the applications would benefit all facets of society."[30] This idea echoes the learning disabilities and minority studies in STEM education literature. Du and Kolmos[31] also suggest methods of improving inclusivity for women engineers, but their approach uses problem-based learning (PBL) courses. In their study, they analyze how PBL courses offer not only the usual learning benefits associated with PBL, but also increased female recruitment into areas where they are under-represented.

The relatively low percentage of women pursuing engineering degrees is also a societal issue. Studies by McCarthy[32] and Chen[33] suggest that negative cultural messages, restrictive role modeling, and lack of constructive middle and high school guidance contribute to the problem. McCarthy advocates fostering inclusive attitudes and language, reframing physical project assessments to foster a less destructive approach, and among other things, carefully marketing STEM education. In another study,[34] researchers found that the perceived importance of engineering competencies is subconsciously influenced by gendered assumptions. Engineering competencies that are perceived as "feminine" are regarded as soft skills that are less valued. As a mitigation strategy, they and others[35,36] suggest emphasizing the value and importance of a wide variety of competencies in engineering, and being careful not to reinforce stereotypes. To be effective, they contend improvement strategies should be structural rather than individualistic.

In general, the literature on gender issues in engineering education shows that the current population of women in STEM education is low relative to the general population and the inclusion of feminine identity plays a key role in the formation of an inclusive environment. University is an essential developmental period for many students, and it is important that women see the opportunity in engineering education of developing in an environment that affords their perspective and goals equal value. A summary of the key advantages and disadvantages of a few different approaches that have been tried in this field is shown in Table 3.

We have reviewed the literature in three clusters that pertain to specific learner populations: students with learning disabilities, minority students and cultural differences, and women. Along

with the literature on these specific populations, there is another body of literature which looks at the learning environment overall.

Design for Retention

There is a body of literature in the field of higher education studies that pertains to retention. The literature in this area can be roughly subdivided into two categories: research into the attributes that make students more likely to succeed (with the aim of helping students boost their competencies in these areas); and research into intervention strategies or environmental factors that impact success.

There is research that demonstrates that the preexisting psychological state of the student, and their social and coping skills, have an effect on retention. Solberg Nes et al.[37] surveyed over 2000 students to determine the effects of dispositional and academic optimism on college student retention. The former affected retention via motivation and adjustment, whereas the latter did the same, but affected GPA as well. One area that has received much attention is Emotional Intelligence (EI) and how that impacts retention. Qualter et al.[38] showed that higher EI positively influences a student's ability to progress, while also evaluating an EI-based intervention program using recent theoretical work to ground their results. This approach is typical. Schools that use EI assessment will generally follow up with the student, i.e. offer opportunities for the student to boost their competency in areas where their EI assessment is low.

Other researchers have focused on retention programs and the characteristics of the learning environment that positively impact retention. Jones and Braxton[39] offer a good current review of the extent and types of recent approaches institutions are taking to reduce college student attrition. Bai and Pan[40] performed an analysis of four different types of intervention. In their study, they found that social integration programs improve retention for female students, and identified which types of advising programs benefited first year students. Croft et al.[41] examined a program which increased support of mathematics instruction to assist in retention efforts, and showed that the institution also progressed in other areas as a result of this university-wide support strategy. McQueen[42] recently reviewed various models that are currently being used in the field of retention. She argues that an internationally prevalent model currently used by institutions for student retention, Tinto's Student Integration Model although useful in certain areas, is not particularly applicable for education. She suggests that a more contextualized, nuanced, and psychosocial approach be used in the field.

The institutional environment, including the student community also plays a key role in retention. Oseguera and Rhee[43] studied how the characteristics of the student population affected retention over a 6 year period. They found that better academically-prepared and better resourced students can act as buffers for at-risk students. That is, the better prepared students can help retain their peers during times of failure and self-doubt.

Overall, we found through the literature search that much of the research, although carried out in other fields, is applicable to engineering education. The issues of student attributes (e.g. EI) and approaches suggested for retention programming appear to be transferable to engineering. The literature suggests that supporting the development of student coping skills, and creating an

environment that encourages mentoring and a positive sense of community and inclusion have a positive impact on retention.

Like the other clusters of work we reviewed, the body of material in this field is huge. There appear to be many possible strategies that could be implemented to positively impact retention. However, we are faced with two difficulties. First, programs or approaches need to be fit to the needs of the particular institution, and simply "lifting" a strategy from elsewhere is probably not effective. So we need to understand not just the details of the strategy, but understand the principles that make it effective. Second, given limited resources we need to decide, on a practical level, which approaches will yield the most impact for resources invested.

Discussion

This review has considered clusters of literature which all pertain to inclusivity and by extension, retention. Within each of these clusters, the authors have examined recent literature with an emphasis on breadth. These topics include up-to-date literature surveys, statistics, and quintessential studies that examine inclusivity across diversity. Although each article takes a unique approach, there are some generalized conclusions which we can draw from this review.

Two schools of thought emerge from the literature examined, both have at their core the intent of increasing student success and retention in diverse learning environments via inclusivity. The individual-focused (IF) approach attempts to mitigate learning barriers by helping the individual student fit into the environment, while the system-focused (SF) approach attempts to change the environment to fit the broadest possible variety of students. All of the strategies and programs discussed in the literature, across all of the clusters we reviewed, can be categorized along this spectrum. Some approaches are purely IF or SF, but many are a mixture.

Tables 1, 2 and 3 summarize some of the main advantages and disadvantages of the IF and SF strategies for each cluster of literature. Table 1 shows how learning disabilities can be mitigated using IF and SF approaches. There is a tradeoff between individual accommodation or intervention and increasing the accessibility of the system overall. The goal in both approaches is to improve inclusivity. However the SF strategy adjusts the system to make the environment more accessible to a greater number of students. This, if done effectively, will improve the learning environment for LD students, and may also create a better learning environment for others (what is known as the "curb cut" effect). It also inherently accommodates students who may have a learning disability, but have not yet been assessed. The disadvantage is that even a system that is well designed for a broad set of users may not accommodate people on the far end of the spectrum in terms of needs. And, there may be a perception that building accommodation into the system compromises the integrity of the education. This may not be the reality, but it can impact on the effectiveness of an institutional change. Whereas, the IF approach targets LD learners specifically and seeks to provide accommodation or teach coping skills. As discussed in sources like Williams et al.,[11] the creation of a personalized relationship between the accommodation service and the student increases a sense of inclusivity while reducing barriers to learning. However, other authors in the field argue that as more and more students resort to accommodation the system becomes strained, and students may become too highly dependent on this service for their sense of inclusion. Increasing load on individual accommodation services

requires greater resources while only meeting the needs of a limited portion of the learning population. Hence, there are disadvantages to using IF or SF strategies exclusively.

Table 1 – Strategies for people with learning disabilities (physical/mental)

Individual-Focused		**System-Focused**	
e.g.	Accessibility volunteer who helps in note-taking, physical assistance for transportation, extended-duration for assessment completion, etc. (per-case basis)	*e.g.*	Universal Design in Education – maximize accessibility for the greatest number of learners possible. Provide an environment that is flexible, transparent, and more tolerant of user-error.
Pros	Provides assistance to individuals who are highest at-risk of not succeeding Demonstrates strong sense of institution-learner commitment due to personalized response	*Pros*	Provides an increased level of accessibility for all students, regardless of prior disability-level Increases universal access to education May promote/supplement alternative ways of learning, resulting from greater variability of access methods
Cons	May promote a sense of unequal treatment among non-assisted and assisted learners Although student is being assisted, they may feel more out-of-place because of accepting this assistance Generally requires greater resources as students are addressed individually	*Cons*	May leave out students at highest-risk of not succeeding There is a concern that this may compromise the integrity of education by "simplifying" Does not address barriers to individual learning specifically (addresses several barriers in a general-sense, but none are specific to any student)
References	8, 11, 17, 18, 19		8, 9, 12, 13, 14

Table 2 shows a comparison between the advantages and disadvantages of using the IF and SF approaches and provides some examples for first-generation, minority and culturally based student issues. The individual-focused strategy typically employs a personal tutor, coaching, or mentoring system. This approach encourages person-to-person interaction, and may greatly benefit individuals who severely lack any support and have a substantial sense of isolation or exclusion. Although the IF approach promotes a kind of inclusion, it also segregates individuals from their peers. Further one may argue that the learner may develop a dependence on this resource, and such dependency could possibly reduce the learner's independent motivation and self-confidence. In terms of adjusting the environment to fit the student's needs (i.e. the SF approach) sources such as Malone et al.[21] suggest that identity creation is a major factor for increasing inclusivity, and the institution can affect this by supporting initiatives that build a sense of community belonging. Further, changing the classroom environment to include applications and contextualization that takes into account a diverse student population can have a

positive effect. However, similar to the shortcomings of the SF approaches used for learning disability, this approach may not meet the needs of the highest risk individuals.

Table 2 – Strategies for first generation and minority students, and/or to address cultural issues

Individual-Focused		**System-Focused**	
e.g.	Personal tutor/mentor assigned to student (or small group) Having clear lines of communication between instructor/learning population by promoting a human-centered approach (telephone, in-person meetings, etc) Individual-specific learning objectives	*e.g.*	Restraining use of colloquial terms on assessment materials Promoting and funding cultural/minority groups on campus whose aim is increase understanding between learning population/society Diversity in methods of instruction allows for the learning population to use the one they are most familiar with (e.g. Lecturing vs. teaching using multimedia)
Pros	Individualized sense of inclusivity – student feels closely associated with 'mentor' Increases self-confidence by having a resource that may know learner at a personal level	*Pros*	Promotes an environment that increases inclusivity for all students to a greater degree Enhances instructional material by contextualizing data generally – improves transferability of knowledge/application Limited 'alienation' feeling due to the learner self-creating a model of effective learning (is not dependent on a 'mentor' for assistance)
Cons	May form dependence on 'mentor' to act as interface between self and environment Addresses very specific issues – knowledge gained may have variable applicability	*Cons*	Learners highest at-risk who need additional assistance still have their barriers to learning
References	20, 21, 22, 23, 25		20, 21, 24, 25

Table 3 considers the strategies available for addressing gender issues in engineering. One example is lack of female role models in engineering education. Using an IF approach an institution might develop a coaching or mentoring program. The advantage of approaching inclusivity in gender-issues from the angle of IF is that it promotes the sense of a personal relationship between a mentor and an individual student, and this fosters identity creation, increased self-confidence, and addresses other issues. A critique of the IF approach in gender issues is that it may promote a sense of exclusion for women because it suggests they are a foreign entity in engineering in need of support to operate successfully in the engineering profession. This may be a source for alienation, and may be counter-productive if not addressed

by the system. The systems-focused approach identifies gender-issues as a way to embrace differences and incorporate them into the diverse learning environment. This approach identifies gender issues not as a problem with women not fitting in, but rather as a part of the greater problem of an exclusive environment which also has implications for other types of diversity. A systems approach aims to address all of these issues via universal design applicable to the greatest number of users to the greatest degree possible. The difficulty is implementing such a change. There are numerous obstacles including societal factors, institutional inertia, etc. And it can be asked whether engineering currently has the means of making this change if there are an insufficient number of women to reach a critical mass, or tipping point.

Table 3 – Strategies to deal with gender issues

Individual-Focused		**System-Focused**	
e.g.	Individual role-models in the faculty who act as nodes for personal growth	*e.g.*	Increasing enrolment rates for women in STEM education
Pros	Highly personal relationship between individual and 'mentor' may increase sense of identity, and decrease self insecurity issues etc. Embraces gender differences as a means to accept diversity in the classroom	*Pros*	Increases gender equality, and promotes universal treatment of all learners Self-identity creation is supplemented by the system addressing all students equally Gender differences are given the same 'importance weighting' as others; does not provide exclusive treatment of one group over another: system-wide
Cons	May further segregate genders because of increased sense of exclusivity between "them" and "us"	*Cons*	Gender issues may not be fully addressed for all persons affected – a surface-level approach to solving this problem promotes a partial understanding of the specific issue
References	26, 27, 28, 29, 33		26, 28, 29, 30-36

Conclusion

Studying student success in learning environments has roots in inclusivity studies in education. Recent literature sources were used for this project which aims to identify means of increasing inclusivity by addressing the needs of students with learning disabilities, minority students and those who have cultural barriers to learning, and women in STEM education. We have also included the literature on retention in the review, particularly design for retention.

The breadth of work examined here was an attempt to create a list of resources which can serve as a starting point for future work. Several approaches currently being investigated in other disciplines, such as an understanding of EI as it pertains to retention, have potential to be used directly in engineering, or to be adapted for use in engineering.

Much of the literature is focused on the benefits of a human-centered approach to revising the learning environment either at the individual level or at the systemic level. The approach could

hypothetically be engineered such that the educational system is designed around the user (students) to address their needs. This is a concept familiar to engineers in product or system design and we have the opportunity to apply our expertise in this area to improve the learning environment. Increased inclusivity will ideally accommodate the increasing diversity of tomorrow's engineering population. However, the challenges of designing intervention programs, or redesigning the learning environment, are enormous and to date there is no one approach can be identified as the "standard" or best practice.

Considering the literature from a purely individual-focused or system-focused perspective is perhaps simplistic because so many of the suggested, and tested, strategies are a blend of these two approaches. However, we need a way of conceptualizing the vast quantity of research to make it meaningful and useable. Creating this framework helps to consolidate the literature in this field into a manageable form. In summary, the individual-focused approach addresses barriers to learning at a personal-level which works best for learners who are most at risk. It is also far easier to implement. However, it may require more resources and reach fewer students as the population diversifies. The system-focused approach on the other hand aims to increase inclusivity for the greatest number of students possible. So, whereas IF focuses on depth, SF focuses on breadth of learning barriers mitigated. The SF approach is harder to implement in many ways and may not meet the needs of the students who most at risk. However, it is geared toward developing a more inclusive environment which should be the goal of every engineering school. Overall, we should be considering both pathways to creating a more inclusive system.

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