STEM PASSPORT PROGRAM LITERATURE REVIEW

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There is no doubt that community colleges play an important role in producing the next generation of scientists and engineers. Community colleges facilitate crucial Science, Engineering, Technology, and Math (STEM) transfer pathways to ensure the success of students seeking to obtain their baccalaureate degrees in a STEM field (Bahr et al., 2017; Meza, 2019). There exist several barriers for students in the transfer pipeline as they seek vertical transfer from a two-year to four-year institution to complete their STEM degree, and as a result, institutions and programs have created various programmatic changes to help spur STEM transfer momentum (Fraley, 2020). In prior research, faculty have felt their administration has failed to recognize the needs of students in the STEM transfer process (Dupont & Rodenburg, 2020) and believe it is crucial to focus more attention on students throughout the transfer process, both in STEM and specifically in engineering. Thus, the following literature review provides information on the landscape of the engineering transfer, barriers to transfer, how institutions are working to improve engineering transfer, and ways to continue the revision of engineering pathways based on learning outcomes to achieve the goals of the Western Interstate Commission for Higher Education (WICHE). WICHE's goal is to create a STEM transfer passport program that seeks to improve transfer efficiency in engineering disciplines, improve curricular structures to improve student retention, increase participation and persistence among underrepresented minorities (URM) in STEM, and increase the numbers of engineering graduates to contribute to the economy.

Engineering Transfer Landscape and Transfer Barriers

ENGINEERING TRANSFER RATES

Transfer students make up a large pool of the eligible STEM graduates who help grow the STEM workforce. Generally, 33% of students graduating from a community college transfer to a four-year institution to continue their education (Jenkins & Fink, 2016). According to recent NSF (2018) research, 52% of science and engineering graduates have attended a community college prior to earning a bachelor's degree. Transfer students also often have a longer graduation timeline of six years to earn their BS in engineering (McNeil & Ohland, 2016; Shapiro et al., 2017). As transfer student numbers continue to rise, it is important to understand the transfer student pipeline and how to support all students. It is also important to consider the transfer data for students who are underrepresented in science and engineering, including women and underrepresented minority (URM) students (NSF, 2017). In past research, women represented 15% of the engineering transfer pipelines among multiple institutions (Knight et al., 2014), and once transferred, they were 41% more likely to suffer attrition in their engineering programs (Cohen & Kelley, 2019). The NSF (2017) defines URM as those who identify as American Indian, Alaskan Native, Black, and Hispanic, and this group of students is less likely to graduate with a STEM bachelor's degree than their white peers. Another snapshot of underrepresented group transfer rates can be seen in longitudinal transcript data research across a community college district in the state of Texas, which found that after transferring, Asian students were the most likely to graduate from the receiving institution, and Sub-Saharan African students had high transfer rates but left STEM fields (Ghazzawi et al., 2020). The prestige of an institution also plays a role in transfer success for underrepresented groups. The more selective and the higher the rank of the institution, the lower the transfer compositions of URM, low-income, and first-generation students, as seen in a study of engineering transfer programs across one state (Grote, 2020). Differential outcomes in transfer (or levels of attrition) for women and URM students highlight the importance of creating models that decrease these disparities.

Institutional bureaucracy also plays a role in student transfer outcomes and student success. Community colleges often have a difficult time developing new strategies for transfer pathways due to limited expertise, shrinking resources, and budget constraints (Enrique et al., 2018). Therefore, having transfer-receptive policies at four-year institutions and initiatives are important; for example, students who plan to transfer in engineering need access to upper-level courses, admissions-conscious advising, and necessary exemptions to ensure their coursework can transfer (Grote, 2020). Articulation agreements and wrap-around services also help establish a framework for successful transfer. In past research, with well-crafted articulation agreements where courses are guaranteed to transfer, transfer students can outperform first time in college (FTIC) students in upper division courses (Grote, 2020). Although articulation agreements are effective in helping students transfer, they do not solve all transfer-related issues. If the department policy restricts admissions, rather than the institution policy, this poses another barrier for students attempting to complete a STEM degree (Lee et al., 2019). Bureaucratic elements of the transfer process influence almost every variable linked to student success, and a large component of that involves course sequencing.

COURSE SEQUENCING AND CURRICULUM COMPLEXITY

As course taking can significantly impact a student's transfer success, there are specific course-related barriers to transferring that students experience, both in course sequencing and the complexity of their curriculum. Engineering, like many other academic disciplines, has a particular course sequence developed to prepare students for a career in the field, as courses build upon one another (Lattuca & Stark, 2011). Because of course sequencing, transfer students often encounter barriers including the possibility of having only technical courses left to take when transferring, which negatively impacts semester transfer GPA (Lee et al., 2019). Course sequencing especially impacts URM students. In an analysis of STEM student success in transfer across multiple states, URM students had lower rates of first-attempt success in science courses, lower rates of advancement in curriculum, and higher rates of exiting without transferring than non URM peers (Bahr et al., 2017). Course sequencing is an important area of focus, to identify where supports may be necessary to boost student success.

Prerequisites also become important when discussing course sequencing; when students lack the ability to take prerequisites at the community college, those students are less likely to pursue a degree in biological sciences or engineering (Glynn, 2019), which leads to attrition. Time to degree attainment can also be delayed if students lack the pre- and corequisites necessary to advance in their curriculum sequence (Grote et al., 2020). At times, community colleges struggle to offer all the courses a student may need to transfer in engineering, which can lead to fewer transfer credits (Dunmire et al., 2016; Enrique et al., 2013) and failure to meet those necessary pre-and corequisites.

Another common barrier to effective transfer is having excess credits, which can be the result of issues in course sequencing. In a quantitative analysis of engineering students across multiple states, 45% of students surveyed had 70 or more units for transfer, and 24% had 86 or more units, as many are transferring before earning their associates degree and taking more coursework than is needed for transfer pathways (Dunmire et al., 2011). This can be the result of students attending multiple institutions to meet the transfer requirements at receiving institutions, which impacts a student's time to transfer and graduation (Dunmire et al., 2011). Without effective course sequencing at the sending institution, it becomes difficult for students to have a smooth transfer to the receiving institution, as they may have extra credits that do not transfer, and must take additional coursework at the receiving institution. Understanding transfer pathways can ameliorate students' taking too many credits, but course sequencing must also be established to help students be successful .

Curriculum complexity can also provide insight into why students face barriers to transfer, and is closely related to course sequencing. Studies have used curriculum complexity metrics to understand how students encounter engineering and the various pathways they can take to obtain their credential (Grote et al., 2020). Frameworks developed for examining curricular pathways can illuminate the instructional and structural complexity of these pathways to understand how courses are taught and why they are sequenced in various ways, recognizing that different engineering disciplines have varying degrees of curriculum complexity (Grote, et al., 2020). There is a strong relationship between curricular complexity and time to degree for engineering transfer students (Lee et al., 2019).

Community colleges play an important role in the success of a student's transfer pathway in regard to curriculum complexity. Students who begin their education at a community college will have a more complex curriculum pathway as a transfer student than a first-time student at a four-year institution (Lee et al., 2019). Community colleges have more flexibility in course sequencing, as those institutions must have a varied science and math curriculum to meet the needs of the entire community college (Grote et al., 2020). This can cause problems for a student in their transfer pathway. The diversification of lower-division engineering requirements, which has increased the breadth of engineering offerings, can lead to bolstered complexity in academic planning, increased number of courses, and elongated time to degree (Dunmire et al., 2011). Inconsistency in lower-division courses can make transfer difficult (Dunmire et al., 2011; Espirtu & Todorovic, 2020); thus, a focus on curriculum complexity and course sequencing among both sending and receiving institutions can reduce some barriers for students in the transfer process.

COURSEWORK IMPACTS OUTCOMES

Math courses in particular are important predictors of success for students transferring in STEM, and especially in engineering. The rigor of a student's math experience matters greatly in student retention (Astin & Oseguera, 2005), particularly in the field of engineering (Li et al., 2009). In an investigation of STEM student math levels at a single institution, the higher the level of math classes successfully completed led to higher odds of transferring to receiving STEM institutions (Fraley, 2020). Calculus is a significant indicator of STEM transfer success and degree attainment (Fink et al., 2021). Black, Hispanic, and Native American students are less likely to complete a crucial STEM pathway course like calculus than their Asian and White peers, who also have an increased rate of transfer momentum and degree completion (Fink et al., 2021). For engineering programs specifically, math becomes even more important. If a student is in the lowest levels of math at the sending institution, they become more likely to transfer away from engineering programs (Cohen & Kelley, 2019). Math completion and program momentum also become important for engineering transfer students, as those who have transferred Calculus I, Calculus II, and Physics I credits to a receiving institution have higher retention and graduation rates (Laugerman et al., 2015). High numbers of math credits lead to successful transfer momentum. Other studies on momentum demonstrate that having nine or more math credits completed prior to transfer are impactful to a student's transfer success, as students had 3.1 times greater odds of university transfer than those who had fewer than nine credits. (Fraley, 2020).

Other research investigates supplemental math programs that seek to support students to be successful in engineering. One such program is Math Jam, a one-week intensive math program that bolstered retention and success rate in math courses, particularly for Hispanic students who had a 19% higher retention rate than their peers who did not participate (Camacho, 2015). Math courses also predict the success of URM students. In an investigation at one engineering institution, academic factors related to math were more important than demographic characteristics in predicting degree attainment, persistence, and other related characteristics (Cohen & Kelley, 2019). Current engineering structures and programs have a differential impact on students from different races and ethnicities, which impacts student retention and degree completion (Ghazzawi et al., 2020; Jenkins & Fink, 2016; NSF, 2017), but programs like Math Jam have shown to be successful for Hispanic students (Camacho, 2015), demonstrating some programming can help support students from diverse backgrounds and help them be successful.

A popular avenue for institutions to facilitate successful transfer pathways for engineering transfer students is offering a transfer seminar course for incoming students at receiving institutions. The USA-LINK NSF funded program at the University of Alabama is one example, providing students with a required student success seminar that focuses on university requirements, study skills, advising and curriculum requirements, career planning, problem solving, and oral and written communication to ameliorate the burden experienced in transfer (Jefferson et al., 2014). A multitude of other transfer success seminars exist that include similar foci, to attempt to reduce institution attrition among engineering transfer students (Bayles, 2016; Bloom et al., 2017; Espirtu et al., 2021; Jones et al., 2012). Some seminars focus on the technical elements of the receiving institutions (Jones et al., 2012), while other transfer seminars are built with a focus on the partnership between the sending and receiving institutions to help streamline transfer (Espirtu et al., 2021). Although there is some research that examines programs that span multiple institutions, most studies tend to investigate the transfer seminar at one institution, as those institutions seek to provide support for their own incoming students.

OTHER BARRIERS TO TRANSFER

Students also experience additional barriers to transfer including lack of transfer knowledge and the experience of transfer shock. In a national survey of students intending to transfer in STEM, many first-year community college students knew little about transfer requirements both generally and at the specific universities to which they hoped to apply (Meza, 2019). Even more challenging, students in that same survey mentioned their lack of knowledge in capacity constrained majors like engineering, thus even if they did transfer, they were unaware of department-specific requirements that might lead to their denial (Meza, 2019). In addition to specific transfer knowledge, longitudinal research conducted at schools within an engineering transfer partnership in Indiana alluded to students lacking familiarity with various transfer pathways they could take, which impacts their retention and progress towards their bachelor's credentials (Mobley, 2014).

Transfer shock also serves as a barrier to successful transfer to four-year institutions. Transfer shock is when students find themselves ill prepared for more rigorous coursework and feel as if they do not fit into the student culture of the receiving institution (Berhane et al., 2017; Mobley et al., 2012). There can exist a disjuncture in academic norms between the sending and receiving institutions, which can make transfer more difficult for students in STEM and lead to academic decline (Elliott & Lakin, 2020). Specific to engineering, African American students in a mixed methods study conducted at multiple institutions in one state experienced the lack of a culture of inclusivity at their receiving institution, which included a lack of faculty role models, lack of participation in co-curricular engineering-related activities, and other institutional supports that help students feel supported as engineering students (Anderson, 2020). Similarly other studies found that creating a community of practice to foster an inclusive culture can help URM students be retained and graduate at their receiving institution (Espirtu & Todorovic, 2020). Transferring can be difficult, and transfer shock can result in student attrition.

In any program, there can exist barriers to successful transfer for students. Transfer success rates are the result of various programmatic elements like course sequencing, articulation agreements, and prerequisite coursework. Students experience many barriers that may prevent them from obtaining a four-year degree, but institutions have sought various strategies to improve engineering transfer rates for students transferring from a two-year to a four-year institution.

Improving Engineering Transfer

CURRICULUM SEQUENCING AND COURSE COMPLEXITY: COURSE TAKING IMPACTS OUTCOMES

Because of the barriers to transfer, institutions and particular STEM programs have worked to improve engineering transfer programs. Students have needed various supports, so many initiatives have focused on helping reduce gaps in knowledge or coursework to reduce attrition in the transfer pipeline. Among the common programs and projects to support students have included changes to curriculum, supplemental coursework, bridge programs, and various institutional changes to bolster retention and graduation numbers.

Curriculum. To improve engineering transfer outcomes, institutions have focused on course sequencing and curriculum complexity to ameliorate issues in the transfer process. Institutions have focused on course taking problems and issues in transfer credit alignment, aligning curriculum, course offerings, and creating new courses to help students learn technical content needed to transfer successfully as a junior (Espirtu & Todorovic, 2020). Creativity in the curriculum pathway for transfer students is a critical component in transfer student success. In Illinois, students earning an AS degree for engineering take two additional math and science courses at their sending institution and then take two general education courses at their four-year institution upon transfer (Lipscomb et al., 2019). This helps reduce the problem of students only having upper-division courses left in their sequence (Lee et al., 2019). Other programs have redesigned the traditional two-plus-two programs creating a one-plus-three program to find a means to better align curriculum requirements based on student outcome data (Fink & Jenkins, 2017).

When examining the curriculum content and learning outcomes, project-based learning (PBL) is a change in curriculum to solve complexity issues. The Iron Range Engineering and Twin Cities Engineering programs both have recreated learning outcomes and curriculum to give students proficiency in the Accreditation Board for Engineering and Technology (ABET)-aligned outcomes framed around PBL (Bates et al., 2020; Chan et al., 2017; Clausen et al., 2021). This has led to students' improved communication, ability to design systems, engagement in entrepreneurial thinking, use of skills, ability to solve engineering programs, and ability to function well in teams (Bates et al., 2020; Johnson et al., 2018). The goal, though, is to design a way to account for credit loss and non-transferable coursework (Grote et al., 2020). To do that, institutions need to work together to develop strategic curriculum pathways.

Coursework. Some institutional initiatives focus on supplemental coursework to support students in knowledge gaps that could lead to attrition. Such coursework can also include supplemental instruction for those courses with high attrition rates to foster student success (Enrique et al., 2018). Some supplemental coursework is targeted at improving materials science knowledge (Dunmire et al., 2016), math and physics context through introduction to engineering courses (Langhoff et al., 2016), or student success seminars. As noted, the inclusion of seminars can impact student transfer success outcomes. Seminars taught in conjunction with engineering curriculum to foster a sense of community and prepare students as they begin their coursework at the four-year institution (Bayles, 2016; Espirtu et al., 2021); transfer students who had not taken the success seminar were almost twice as likely to earn a D, F, or W grade in corresponding engineering course (Bayles, 2016). Students in other success seminars have found transfer enrollment to increase 15% with only 13% attrition compared to non-participants with a 45% attrition rate (Jefferson et al., 2014). Supplemental coursework is effective in helping students who have knowledge gaps or other transfer barriers.

Adaptive Learning. WICHE Cooperative for Educational Technologies (WECT) which is part of the larger Every Learner Everywhere initiative, has recently compiled a set of resources for online learning, including extensive information about adaptive learning for student success that covers STEM gateway courses (WCET, 2021). For example, one study WCET reviewed noted that adaptive courseware in gateway math courses at multiple institutions was successful in enabling students to achieve necessary corequisite and basic skills. Another case study – this one from Portland State University -- showed a significant reduction in D-F-W grades in "foundational" courses using adaptive courseware. Beyond improving pass rates, the ability of adaptive learning platforms to focus on specific learning outcomes may hold promise in any effort to ensure that students achieve identified essential learning outcomes rather than simply passing courses.

Bridge Programs. Finally, institutions and partnerships have looked to developing bridge programs with specific coursework, with admissions support, and with faculty development programming. The goal of any bridge program is to help the recruitment and retention of students in the transfer pipeline, and many institutions offer these bridge programs to bolster retention rates (Jacquez et al., 2005). Some bridge programs focus on math specifically to help students progress more quickly, increase their awareness with math tools, and develop a community among those transfer students who are part of the bridge program (Enrique et al., 2019). Improving math proficiency in a summer bridge program is also a means to positively impact URM retention and graduation (Espirtu & Todorovic, 2020). Bridge programs can also offer special topics engineering courses that are coupled with academic and financial workshops. Lastly, other bridge programs focus on faculty involvement as is evidenced by summer STEM teaching institutes (Enrique et al., 2018) and faculty development opportunities like curriculum development (Bates et al., 2020). In one state-wide partnership, faculty will teach bridge courses at both two-and four-year institutions to help align curriculum and bolster outcomes (Oglivie & Knight, 2019), which demonstrates the importance of curriculum alignment to bridge course learning outcomes to help ensure students are prepared.

TRANSFER KNOWLEDGE AND REDUCING TRANSFER SHOCK

As students navigate the transfer process, two important topics arise: transfer knowledge and transfer shock. Some students need extra support in the areas of advising or mentorship to help them feel included. Advising is an important component in the vertical transfer process. Many of the programs that are attempting to provide wrap-around services for students discuss the guidance students need in the process including that for course-taking, how alignment issues between their sending and receiving institutions impact them, and how there could be incompatible course requirements for their associate degrees as they transfer (Karandjeff, et al, 2011; Oglivie & Knight, 2019). Intentional advising practices are crucial for transfer student success (Espirtu & Todorovic, 2020). The same holds true for students from diverse backgrounds, as in a survey of 306 engineering students, 88% of which were Hispanic, academic advising needed to be improved (Oglivie & Knight, 2019). To help support students in the advising process, programs have instituted more training for advisors at the receiving institution (Oglivie & Knight, 2019), encouraged advisors to provide more information and guidance on STEM careers, which has helped reduce attrition (Jackson, 2013), and give students more agency in the advising process, which has been particularly important for African American engineering students (Anderson, 2020). Although advising is only one piece of the transfer puzzle, students have a need for strong advising resources to be successful in vertical transfer.

Akin to advising, mentorship has shown to be an effective strategy in student retention and graduation. Research has shown that bonds with other students and faculty had significant relationships with learning outcomes in engineering as students have had more integration with project design and working in teams, both important learning outcomes in the field of engineering (Marra et al., 2015). Many programs seek to provide mentorship as a facet of its overall goal of improving transfer student retention like the Maricopa Engineering Transition Scholars (METS) program in Arizona; the METS program holds "Be an Engineer" events that include mentoring, and with 48.7% of participants identifying as URM and 31% women, retention in the engineering program has grown from 53% in 2000 to 89% in 2005 (Anderson-Rowland et al., 2005). Peer mentorship, specifically, also plays a role in student success in engineering, as programs like the ASSETS program in Tennessee have established peer cohort models with trained peer mentors, which has been successful in bolstering transfer student retention in engineering programs (Fomunung et al., 2020). Mentorship also contributes significantly to student success. All of this demonstrates the student-centered educational approach needed to support transfer students in their journey (Fomunung et al., 2020). Mentoring plays an important role in student retention and graduation post-transfer, and successful programs have validated the need for continued mentorship programming.

Students seek both a sense of belonging and the ability to self-identify as an engineer. When transfer students feel as if they belong and self-identify as an engineer, they are more likely to be retained (Andrews et al., 2019). An inclusive environment is important to help student success be realized in the transfer process in STEM and engineering (Duis et al., 2016; Laugerman et al., 2019). Programs that intentionally created an inclusive environment and learning community have led to an increase in pre-engineering students, more transfers, and bolstered first-year retention rates while women's participation rose from 7% to 17% and underrepresented minorities from 5% to 16% since the start of the program (Laugerman et al., 2019). When students feel part of a science culture, they are more likely to be retained, which has certainly been the case for students with varied identities including social class, gender, age, race, immigration status, and religion for students at a single STEM transfer program (Dupont & Rodenburg, 2020). For African American students in STEM, socialization in STEM fields has been important for transfer from community colleges to Historically Black Colleges and Universities (HBCU) (Jackson, 2013), and often, that socialization is actualized in student support models aimed to break down barriers to inclusiveness and fostering a local community of practice, which has also shown to be effective in the retention and graduation of underrepresented groups in engineering programs (Espirtu & Todorovic, 2020). The creation of an inclusive environment is critical for student retention and success, which demonstrates why many programs are seeking to provide such an environment for their transfer students.

INSTITUTIONAL INITIATIVES TO REDUCE OTHER TRANSFER-RELATED BARRIERS

Both sending and receiving institutions work to reduce barriers for students in the transfer process, and some of those initiatives focus on partnerships. The key to fixing the transfer pipeline resides at both institutions and in their partnership with one another (Fink & Jenkins, 2017). First, articulation agreements are a critical component of most transfer partnership discussions and have been on the rise nationwide for years (Kisker et al., 2011) and are often institution-driven (Lipscomb et al., 2019). These documents can help to encourage dialogue about expectations in transfer pathways (Elliott & Lakin, 2020), but they are only one component of successful transfer programs and are insufficient alone to improve the STEM transfer success (Dowd, 2012). Among institutions, annual meetings to discuss learning outcomes as it relates to transfer partnerships are also crucial, as it facilitates what adjustments need to be made for student success (Fink & Jenkins, 2017). Other admissions programs in engineering specifically, like the Engineering Admissions Partnership Program (E-APP), focus on the admissions component of the transfer process. E-APP includes coordinated academic advising, peer mentoring, campus visits, and online social networks to retain transfer students at a rate 10% higher than their non-E-APP peers (Laugerman et al., 2013). By focusing on areas other than credit transfer, programs have helped bolster the success of transfer students.

Industry partnerships are another means by which institutions attempt to improve the transfer pathways for students transferring from two-to four-year programs in engineering (Enrique et al., 2018; Ghandi et al., 2016). Some programs connect students to industry partners starting with orientation and continuing throughout the remainder of their program (Johnson et al., 2018). Another engineering partnership with an electric company in Missouri found better recruitment, retention, and graduation of minority engineering students, with transfer students graduating at a 70% rate (du Maine & McGuffin, 2003). Despite the triumphs of industry partnerships in ameliorating problems in the transfer pathway, the examples of industry partnerships are more limited in scope to small groups of institutions that have two-and four-year institution partners. But generally, effective transfer partnerships that seek creative input from industry have the potential to be successful.

There are a variety of other strategies and initiatives that institutions implement in partnerships to effectively help students in the pipeline. First, on a macro level, receiving institutions must address transfer issues in their missions and strategic plans, as a strategic plan must allow for innovative strategies to support transfer students who often have complicated transfer pathways to ensure their success (Fink & Jenkins, 2017; Glynn, 2019). Additionally, focusing on assessment and data sharing among transfer partnerships can illuminate the need for better assessment and an understanding of learning outcomes for students transferring in engineering programs (Brown & Rhodes, 2016; Fink & Jenkins, 2017). Even simply focusing on coordination at receiving institutions to document transfer coursework more quickly can help ease the transfer burden for students (Oglivie & Knight, 2019). Finally, in any transfer research, the topic of student funding arises. Financial support is an important topic of concern for many students in the transfer pipeline (Fomunung et al., 2020; Johnson et al., 2018; Oglivie & Knight, 2020). As a result, some institutions have focused on funding as part of their strategy to help support students by means of workshops and orientations to clearly outline the finances associated with transfer (Johnson et al., 2018), providing further scholarships (Bloom et al., 2017), or devoting funds to STEM-specific work study awards (Dowd, 2012). Although financing is not the only barrier to successful transfer, many programs have attempted to incorporate some type of assessment or data sharing, better processing strategies, or funding education or resources to support students in their approach to sustaining transfer partnerships.

As the transfer landscape and barriers demonstrate, much of how the transfer pipeline is being improved by institutional priorities aimed at correcting students in some fashion. Whether it is bolstering math instruction, or developing a transfer seminar, the institution seeks to help the student rise to institutional expectations rather than modifying institutional priorities. Fixing the pipeline also hinges on how partnerships work together to ensure programs are implemented effectively. As WICHE seeks to revise engineering pathways based on learning outcomes, it is important to review innovation in the transfer pathway to understand how a STEM passport program could be possible.

Revising Engineering Pathways Based on Learning Outcomes

There have been many efforts to ameliorate the problems associated with STEM and engineering transfer pathways. Many of those efforts are bureaucratic, aimed at helping students fit into the transfer pathway that already exists with bridge programs, math supplemental coursework, or admissions support. Further reform effort is sought by WICHE to develop a mechanism for reimagining the transfer pathway, by focusing on learning outcomes rather than courses. The ultimate goal is to optimize the STEM, and specifically engineering, curriculum pathways to help seamless transfer for students with minimal to no credit loss to reduce attrition in the STEM transfer pipeline. Because there lacks abundant research on STEM transfer using learning outcomes, the following outlines various initiatives like the Open Syllabus Project, a new naming convention for courses, and various updates to curriculum and learning outcomes, all of which can illuminate ways in which a STEM passport could be successful and is necessary to rethink the ways in which the transfer pipeline can be supported

OPEN SYLLABUS PROJECT

The Open Syllabus project also offers insight into WICHE's ultimate objective to develop transfer pathways based on learning outcomes. The Open Syllabus Project is an open, public repository of syllabi analyzed by a non-profit research organization to support education with the goal to foster innovation among educators, to improve the relationship of higher education, and support job market needs (Open Syllabus, 2021), with a syllabus viewable to the public, editable, or able to be commented on by students (Bali et al., 2020). An important component of the conversation of STEM and engineering transfer is the impact on underrepresented groups, and a course syllabus plays a role in fostering inclusivity for students, making them feel welcome and part of the learning community. Though, the open syllabus can be problematic if only students from dominant cultural backgrounds do participate (Bali et al., 2020). If done well, open syllabi, and more generally open educational practices, can promote process-centric, learner-centric, and social justice-focused practices that can address economic, cultural, and political injustice (Bali et al., 2020). Learner-centric syllabus and educational product creation is possible, as studies have used open syllabi and an automated process to create an automated and collaborative book tool that provides insight into textbooks that fit well for particular syllabi and learning outcomes (Petiwala & Moudgalya, 2012). This example demonstrates the ability to incorporate syllabi components to spur an automated process to help students in a learner-centric way, which supports the objectives of WICHE.

CANONICAL COURSE NAMES

Course naming also plays an important role in the ability to facilitate easier transfer for students. In research conducted by Heileman et al. (2018), course names vary across institutions. For example, a four-credit course at one institution could be a three-credit with a one-credit lab at another and have two different names. Institutions should use canonical course names, e.g., instead of naming a course Math 192, labeling it as Calculus 1, to help with the ability to compare courses across institutions and to find common patterns within a discipline (Heileman et al., 2018). Finding common patterns and considering prerequisites among institutions are crucial for curriculum reform efforts (Heileman et al., 2018). As with the automation of the textbook process with the Open Syllabus Project, it seems that course naming, and ultimately the labeling of learning outcomes, needs to have some sort of standardization and pattern to help ensure reform efforts are successful.

LEARNING OUTCOMES

In addition to other efforts to rethink engineering transfer pathways and mechanisms for student success on those pathways, some literature exists on the means to revise pathways based on learning outcomes rather than curriculum. This strategy is akin to considering transfer models as an ecosystem instead of a pipeline, where programs seek to be more innovative to produce student flexibility to foster student success (Lord et al., 2019). This has already been occurring in general education, as general education passport programs exist, including one in the state of Virginia that includes 30-36 general education standardized transfer credits for all AA and AS in the state, with a focus on 8-10 clearly outlined learning outcomes (Lipscomb et al., 2019). Focusing on learning outcomes as well is the Association of American Colleges and Universities (AAC&U) (2015), has developed the Liberal Education and America's Promise (LEAP) Essential Learning Outcomes that cover outcomes like intellectual and practical skills, and knowledge of human cultures that all serve as umbrellas for more subtopics (AAC&U, 2015). The overarching nature of the LEAP outcomes could be a model for the WICHE STEM Passport program, as creating broad categories of outcomes with subcategories can organize important learning outcomes to help facilitate the development of a transfer program based on learning outcomes instead of courses.

A focus on learning objectives is not a new concept, but there are several considerations necessary to ensure the success of reform based on learning objectives. First, the way in which programs are articulated also matters. It is widely known the role that articulation agreements play in transfer pathways (Dowd, 2012; Elliott & Lakin, 2020; Fink & Jenkins, 2017; Kisker et al., 2011), but when those agreements articulate programs rather than courses, it helps to align lower division curriculum to promote successful transfer pathways (Dunmire et al., 2011). Another example regarding articulation can be seen in British Columbia, where STEM transfer reform efforts have created a common first-year curriculum with transfer agreements made across the province, with the goals to expand to connect both private and public education sectors, and recognize transfer curriculum as a credential (Dick, 2017). Another interesting requirement in the STEM transfer reform efforts in British Columbia was the quality assurance process instituted, which required instructors of first year curriculum to have a professional engineering credential (Dick, 2017). Finally, other considerations in reducing curriculum complexity through new initiatives include delay factors: how courses must be completed in order, blockability: how courses are gateways to other courses, centrality: how courses are core to the curriculum based on the number of prerequisites, and reachability: the number of courses that must be completed (Heileman et al., 2018). As learning objectives become the focus of reform efforts, several factors will need to be considered to ensure the success of the reform.

ABET Accreditation and Learning Outcomes. There has also been reform specific to engineering and learning outcomes, both specific to an established program and in evaluation of curriculum across institutions, as it relates to the ABET accreditation standards. First, Iron Range Engineering (IRE) was intentionally developed with a focus on outcomes rather than courses to give students proficiency in ABET-aligned outcomes, framed in a new way while promoting industry partnerships (Bates et al., 2016). Redesigning the curriculum in this way has allowed IRE to create an engineering culture that helps students develop an engineering identity, become members of the engineering community, and outperform their peers at traditional programs (Bates et al., 2016). A focus on outcomes rather than inputs also means less issue with exact course numbers or titles on transcripts for students coming in with two-year degrees, which mirrors the Heileman et al. (2018) research focus. Although there are now seven learning outcomes (ABET, 2019), which is different from the learning outcomes for IRE, the focus on the ABET learning outcomes for IRE transformed the ways in which students are prepared for the workforce.

A second example evaluated engineering curriculum across 12 institutions, which included fifteen core courses using the Open Syllabus project to discover the prevalence of environmental content throughout the curriculum to meet ABET outcomes (Sprouse et al., 2021). Institutions were ranked based on how environmentally conscious their programs are, and generally, across programs and states, environmental education in engineering should be less technical and attainable (Sprouse et al., 2021). Although this project looked at only one student learning outcome, it demonstrates the propensity for successful evaluation of learning outcomes across programs based on ABET accreditation with a framework about how faculty can work together to align curriculum and outcomes (Sprouse et al., 2021). The WICHE STEM passport program can emulate the learning outcomes development of IRE and the focus on environmentally conscious engineering across mechanical engineering programs to develop seamless transfer pathways in engineering based on outcomes rather than courses.

Conclusion

The current STEM transfer landscape depicts a pipeline to graduation that has seen improvement but still contains barriers for students. Different barriers include curriculum complexity and issues with prerequisites, course sequencing, misadvising, among others. Institutions have sought to improve engineering transfer pathways in a multitude of ways. Some have developed supplemental coursework, bridge programs, creating inclusive environments, and other institution-focused directive to help the transfer pipeline. Institutionalization of programming is important (Jacquez et al., 2005), which means a strong commitment is crucial to ensure reform is successful. Although less research exists on revising STEM transfer pathways based on learning outcomes, a foundation for understanding lies in the successes surrounding the Open Syllabus Project, investigating canonical course names, and new strategies for revising learning outcomes.

This literature review demonstrates the importance of understanding these complexities in changing how transfer pathways function across institutions. WICHE's project seeks to develop a Student Learning Outcome (SLO)-based process for curricular complexity analysis that can identify structural challenges within a curriculum, such as areas in which a pathway creates needless delays, and guide curriculum improvement efforts. Students who transfer from two-year programs to four-year programs should be able to complete an engineering degree without excessively extending their time to graduation, which jeopardizes completion. Ultimately, WICHE seeks to: 1) fully understand the state of the knowledge on how to support students who transfer from a community college into a four-year engineering degree program and 2) create a process that brings multiple institutions together to analyze engineering curricula in terms of common student learning outcomes to reduce curricular complexity and streamline engineering degree transfer pathways.

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