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Use of a multi-level self-study to engage campus stakeholders and improve STEM student learning outcomes

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Abstract

Spurred by longstanding concerns about inequities in STEM learning outcomes, including among students in a university's growing engineering and computer science programs, a small team of faculty and staff at a midsized university undertook an institution-wide initiative to understand its entire STEM learning environment, i.e., the conditions that inform student learning inside and outside of the classroom. But first, however, the team had to determine how best to develop and implement a manageable, multi-level self-study that could offer meaningful insights into the complexity of barriers to STEM student success—and then begin to propose meaningful solutions. This paper describes how a diverse campus team designed and implemented such a self-study, and how a similar approach can be adapted for use at other institutions of higher learning seeking to improve STEM student success, including students enrolled in computer science and engineering. The work described here is part of a larger study that is ongoing. Subsequent stages of the study involve deeper analysis of the data, especially within each of the stakeholder groups.

Introduction & Literature Review

Nationally, there are widely known, persistent inequities in STEM student outcomes. This study has its origins in concerns about inequities, but concerns were accompanied by a skepticism about simplistic diagnoses of the problem. Inequitable student outcomes have strong associations with race and family income, which can be proxies for access to quality secondary education and parental college achievement [1], but there are other factors at work. Students pursuing STEM majors in college often suffer even worse outcomes than their non-STEM peers, with students from underserved groups experiencing much lower retention rates (i.e., retention in a STEM major and retention in college generally) and graduation rates [2]. Among STEM majors, gender adds another burden, with women often facing the so-called "gender grade penalty" in STEM classes relative to their male peers [3], [4]. Computer science in particular faces a dual problem with regard to low participation by women: recruiting and retention [5].

Even as the factors of race, gender, and family income remain highly relevant for understanding uneven outcomes, an increasing body of research suggests that the problems faced by STEM students are much more multifaceted than assumed, particularly when trying to serve low-income, first-generation, and students and those from other historically underrepresented/ historically underserved (UR/US) groups in STEM. A small team of faculty and staff at a midwestern, comprehensive university was determined to a find a way to understand these complexities in ways that were manageable, meaningful, and actionable. Note: the authors of this paper are aware of the limitations of many common terms or acronyms used for historically marginalized, excluded, or underserved groups, as well as constantly evolving norms (e.g., BIPOC, URM, LGBTQ+, “minoritized”) [6], [7], [8]. Thus, this study has elected to use UR/US as a shorthand to describe persons from groups that are underrepresented (UR) or underserved (US) in higher education by some means, including but not limited to: some entity related to STEM education (which has often excluded persons from diverse backgrounds); acts or systems of racism or discrimination; family income, family college background, heritage language, or precollege preparation; and residency, citizenship status, or nationality. This study largely focuses on inequities related to gender and race, because data for those demographic identities were the most reliable and widely available.

Approaches to the “student level problem” typically focus on inequitable outcomes among different student demographic groups, try to understand impediments and barriers, and then implement solutions (interventions) that seek to flatten those inequities (e.g., DFW rates, retention in the major, graduation, etc.)[9], [10]. “DFW rate” refers to percentage of students enrolled in a given class whose semester final grade is D or F, or W (for withdrawal after the add/drop period but before the end of the semester). However, in recent years, the literature on STEM student success has shifted *away* from the so-called deficit mindset [11], which posits a need to fix students and make them better equipped to withstand the rigors of STEM education, and *toward* a focus on institutions, with an expectation that they—not the students—are responsible for creating the conditions that lead to more equitable outcomes [12].

Even as the team knew that a better grasp of the complexities of the student experience was critical to removing barriers and improving equity, they also knew that they needed to understand school-level factors that shape STEM education. However, their approach to school-level factors departs from an approach taken by other studies, which have focused on such institutional factors as faculty-student ratio, school size, school type, and undergraduate population diversity [13]. Instead, the team sought to investigate the ways in which learners’ experiences are shaped by key facets of the entire learning environment, such as faculty attitudes, advising support, approaches to DEI, and student sense of belonging and self-efficacy. When students face multifaceted barriers, educators and administrators are obliged to explore multifaceted solutions [14]. For this reason, the team sought to understand barriers from multiple perspectives using quantitative and qualitative data.

Methods

The current study describes the development and implementation of an institutional self-study at a mid-sized, midwestern, private, comprehensive university (the University). The study is oriented toward improving STEM student success, and is ongoing. The portion of the study covered in this article addresses two research questions:

1. How can a college or university design and implement an institutional self-study that explores the complexities of STEM student success and identify barriers to STEM student success?
2. How can a college or university use a multi-level self-study and its findings to engage campus stakeholders and change campus culture in ways that will improve STEM student learning and STEM student outcomes?

To launch this work, the university's provost convened a small team to lead an institutional self-study. The team comprised four STEM educators (geology, chemistry, engineering, and health sciences), three of whom of whom were also positional leaders with college/school responsibilities. These same three team members each had more than twenty years of teaching experience. The team also included: a senior staff professional with responsibility for campus-wide advising; the director of the University's Women's Center, who is a social science researcher with competencies in STEM education; and an outside consultant who was familiar with the institution and could help to facilitate the self-study. The team included men and women who are Black, White, and/or Hispanic. The team met weekly for nearly two years. Mid-study, the team added a staff data specialist along with a staff member from the University's center for diversity and inclusion. This team was charged by the provost to use the self-study to understand—and improve—STEM education across the University.

Since all of the team members were either STEM educators or were deeply familiar with inequitable learning outcomes in STEM at their University and nationally, they had a strong urge to turn the conversation toward solutions to known problems—in their discipline, in their department, etc. Known problems included high DFW rates and significant disparities in DFW rates between discrete demographic groups, in a set of nine foundational STEM courses that enroll students from all undergraduate STEM programs, including engineering and computer science, and one foundational humanities course, for comparison, that is required for all majors. These courses are: Biology I, General Chemistry, Organic Chemistry, Precalculus Math, Introductory Calculus I, Analytic Geometry and Calculus I, Introduction to Statistics, College Physics I (primarily for biology and dietetics majors), General Physics I—Mechanics (primary for engineering and natural science majors), and Global History. The demographic distinctions were: American Indian/Alaskan Native, Asian, Black, Hispanic, Native Hawaiian/Pacific Islander, Non Resident International, Two of More Races, White, Female, Male, No Pell Grant, Pell Grant, Not First Generation, and First Generation.

The team found disproportionately higher DFW rates among UR/US students compared to their white peers (typically the highest-achieving group), but were disappointed to find that some of the equity gaps were even greater than suspected [15]. For example, American Indian/Alaskan Native students had the highest DFW rate of any group, followed by Black, non-Resident International, and then Hispanic students. In some classes, certain demographic groups had DFW rates that exceeded 40%. Nearly all non-White students had double-digit DFW rates in nearly all of the ten classes. The team was aware that any incidences of DFWs have a negative impact on students—from delaying degree progression, to financial burdens caused by having to retake required courses, to provoking a loss of confidence among otherwise capable students. But, as the team developed a working strategy, they found that they needed additional information about the underlying causes of these disparities before they would be able to propose meaningful and sustainable solutions.

The guiding principle implicit in the team's work was prudence, because there was such a temptation to jump to solutions. Prudence is an old-fashioned notion, to be sure, but it has enduring relevance for justice-oriented work—which is how the team saw its labors. In the 13th century, Thomas Aquinas, borrowing from Aristotle and Augustine, defined prudence as an intellectual virtue [16]. It is a command to seek the truth and a guide to right action. Moreover, prudence is not only a private virtue, but also one that serves the common good. Aquinas understood the exercise of prudence as constituting three "acts": **counsel or deliberation; judgment; and action**. Rendered as a method that is widely known in faith-based social justice work—"**see, judge, act**,"—Aquinas' approach to prudence offers a way for a justice- and equity-minded teams to order their work [17].

Defining "STEM Student Success"

The true work of the self-study began with the team's discussions of positive student outcomes, i.e., the University's ideals for markers of student success for all students, understood as the common good. To clarify, the common good does not mean "the greatest good for the greatest number of students," and it does not mean "good overall outcomes" such as positive trends in average retention rates. Rather, the common good is the sum total of conditions which allows all groups and individuals to flourish. With this concept of the common good in mind in mind, the team returned again and again to ideal student outcomes. As tempting as it was to propose solutions and innovations (**act**) early in the process, the team needed to engage in structured conversations that centered the educational and personal outcomes that all University students deserve, and that educational institutions have an obligation to achieve. Put differently, the team was ill-prepared to improve STEM education without discerning what the signs of a changed institution might look like for its own students (**judge**). Any proposed changes had to be closely tied to improved student outcomes. And, if the University were to improve student outcomes, the team had to understand the experiences of its students and its educators, as well as the ways in which different facets of its institutional culture stood in the way of student success. The team also had to seek wisdom that could be drawn from other contexts, such as research literature and findings from other institutions (**see**). The order of the steps mattered if the team wanted to achieve meaningful results.

To begin the process of seeing before judging and acting, the team developed a set of guiding questions that could shape its work:

1. From an institutional perspective, what outcomes are most important for students, individually and collectively?
2. How does the team and the University define or measure these outcomes?
3. What are the barriers to achieving these outcomes, and where (within the University) can those barriers be found?
4. Which domain of the University has the most direct responsibility for any given barrier or future solution?
5. How will the University know that a specific solution is appropriate, and how will the University know if it is effective?

In addressing questions one and two, the team tried to remedy an institutional gap. Even as the University had a well-known institutional mission statement, and various STEM departmental missions, and offices across campus that focused on student success, the University did not have a definition of student success or STEM student success, and it did not have a strategy for achieving student success beyond metrics for retention and graduation. Thus, there was neither a clear destination nor a map for improving STEM student outcomes, only a sense that the

University was not where it wanted to be. In response, the team created a set of equity-minded student success outcomes, which are as follows:

Equity-Minded Student Success Outcomes
• Equity/parity in learning outcomes, especially course-level performance, retention, graduation
• Equity/parity in opportunity, e.g., participation in research/experiential learning
• Sense of self-efficacy and metacognitive skills. • Sense of authentic belonging (can take many forms)
• Ability to "right the ship" when struggling • Capable of linking and applying knowledge across disciplines
• Developmentally appropriate vocational & personal discernment • Knowledge attainment that *students* think they
• Knowledge attainment that *faculty* think students need • Prepared and encouraged to address major societal challenges

Figure 1: Equity-Minded Student Success Outcomes

This study is the team's attempt to address question three, above, for the entire self-study.

Seeing the Barriers

Once the team had developed a set of equity-minded student success outcomes to serve as the self-study's north star, they felt prepared to explore possible barriers and impediments by engaging campus stakeholders (***see***). The team identified three key groups: STEM and former STEM students, STEM faculty educators, and staff professionals connected to student advising or student success. Stakeholder interviews are not a novel means of collecting data, but the absence of literature on this type of multi-level engagement around STEM education suggests that the team's approach was innovative.

Race, racism, and feelings of exclusion/belonging factor prominently in higher education learning environments, including in STEM, and have an outsized impact on students from UR/US groups. The team considered very carefully considered ways to gather information about the experiences and perspectives of persons from UR/US groups [18], [19]. In particular, the team weighed the importance of hearing directly from persons from UR/US groups about their experiences, with the acknowledgment that asking people from UR/US groups to retell negative experiences of exclusion for the utility of others is itself an unfair burden. The team also acknowledged the inappropriateness of asking individuals to be spokespersons for an identity group so that the study could infer the experiences of many from the experiences of one. For this reason, persons from UR/US groups were included as part of all stakeholder groups.

For *student stakeholders*, the team conducted a two-part study: focus groups and an anonymous survey. The student study was implemented by a sub-team comprising a team member who is a social science researcher, along with two part-time undergraduate research assistants who were paid for their time and effort. The student facet of the study was concerned with perceived barriers, inside and outside of the classroom, that could affect student success and persistence. But, beyond asking students about perceived barriers, the team used the occasion of the study to ask students for their ideas of how the University can improve the learning environment. The team validated students' experiences by asking for their input and gave them a voice in a major institutional effort to improve STEM education [20].

The first stage of the student study consisted of conducting ten focus groups, held over a two-month period. The focus groups included 57 current STEM students (i.e., formally enrolled in a STEM major program of study) and five former STEM students (i.e., the student had previously been formally enrolled in a STEM major but had transferred to another major program of study). We used the UCLA HERI definition for STEM majors [21]. The majors represented in the STEM focus groups included: Mechanical Engineering, Health Sciences, Discover Engineering, Chemical Engineering, Industrial Engineering Technology, Dietetics, Computer Engineering, Electrical Engineering, Discover Sciences, Civil Engineering, Environmental Biology, Mechanical Engineering Technology, Geology, Electrical and Computer Engineering Technology, Psychology, Aerospace Engineering, Pre-Medicine, Sustainability, and Biology. The new majors represented by former STEM majors included: Marketing, Sociology, and Women's and Gender Studies.

For current and former STEM and former majors, potential participants were recruited in the following ways:

- email invitation sent to academic units that enroll STEM majors and deans' offices with currently enrolled STEM majors, with a request that the email be forwarded to students
- email invitation sent to non-academic offices that support historically marginalized and historically underserved students, with a request that the email be forwarded to students served by those offices
- email invitation sent to relevant student organizations whose membership is based upon choice of major and/or social identity (e.g., Society of Women in Engineering, National Society of Black Engineers, etc.), with a request that the email be forwarded to the entire membership of that club or organization
- email invitation sent to academic advisors or other university employees who work directly with students (such as student organization advisors, residence life, advising center, etc.), with a request that the email be forwarded to students
- through flyers displayed on bulletin boards across campus
- through social media posts distributed to student-facing offices and academic units
- through network sampling
- through referrals from other students participating in the study (i.e., snowball sampling)

Focus group participants were compensated with a $10 e-gift card for participation in the study. Those who completed the survey were entered into a raffle to win one of ten $10 electronic gift cards. Survey participants had the option to enter the raffle and were redirected to a Google form to submit their contact information to enter; the Google form was not linked to their survey responses. All focus group participants completed an anonymous demographic information sheet.

Focus groups were audio recorded or recorded via Zoom. Following each session, each sub-team member who attended a focus group created an initial summary of that focus group session. After all of the sessions were completed, the three-person study team divided the focus groups and independently reviewed the sessions that they did not personally attend to identify the major themes that emerged in the conversations. The sub-team then met together to review findings and analyze data. Analysis of the data was informed by grounded theory, a qualitative research method that uses data to generate theory, rather than allow theory to inform interpretation of the data [22]. In this approach, the researcher analyzes the data with no presuppositions about the nature of the responses. The task of the researcher is to interpret these meanings embedded in these responses and attempt to generate some possible thematic areas that arise from the perspective of the respondents. Iterative data collection will be shaped by the coding of this first round of data collected from students, with their unique perspectives and experiences. See below, under "Results," for a preliminary summary of findings.

For *faculty stakeholders*, the team implemented a study component on faculty perspectives, specifically, DEI approaches, pedagogy, attitudes about campus climate and student success, and other topics that would help the team to understand the University's STEM learning environment. To recruit faculty study participants, the team adopted a targeted strategy that differed from the approach taken for students. The team sought to include faculty drawn from all of the University's academic units that enroll STEM majors, faculty who represented various career stages and disciplines (e.g., non-tenured math professor, senior tenured engineering professor), faculty from different gender and racial identities, and perhaps most importantly, faculty with differing attitudes (known or perceived) toward student success and DEI. The team generated a preliminary list of STEM faculty and then, to expand it, solicited more names from deans, associate deans, and staff professionals who worked directly or indirectly with STEM faculty (e.g., an advisor who served STEM students and interacted with STEM faculty in that staff role). A personalized email was sent from the team lead to each prospective faculty participant. The invitation included a statement that the faculty member's responses would be anonymized. Using a preliminary list of more than thirty faculty who were invited to take part, the team selected two cohorts of ten faculty, ensuring that each cohort had a mix of men and women, and faculty from different disciplines. For their participation, faculty received a stipend at the end of the study, which recognized their time and contributions to improving STEM learning at the University. Payment of the stipend was contingent upon the faculty member's participation in all three cohort meetings and completion of follow-up questions.

The faculty study had two components: three face-to-face (zoom) cohort meetings of an hour each, and written, follow-up questions that were sent out after each cohort meeting using a google form. The self-study team developed a set of nine guiding questions—three for each cohort meeting—to generate conversation and elicit faculty perspectives. Each cohort meeting opened with a reminder that comments and responses would be anonymized. The team's outside consultant facilitated the cohort meetings, with the assumption that faculty might speak more freely with someone who was not their faculty peer. For the same reason, the cohort meetings were not recorded to encourage faculty to speak freely. The consultant took notes, and then shared with the team the key themes, along with anonymized notes and survey responses. Since the cohort meetings took place on zoom, and the faculty know one another, their remarks were not anonymous. However, participants were asked to maintain confidentiality with regard to anything said during the cohort meetings.

Inclusion of the perspective of *staff stakeholders* was deemed critical to the study. Whereas the faculty perspective was fundamental for understanding "where are we?" in the University's journey to improve STEM education, the team decided early on that staff professionals who focus on student success were an equally critical part of the STEM learning landscape. Staff professionals interact with students and faculty in ways that give them deep insights into the learning environment (positive and negative), and they often manage student concerns that relate directly to faculty-student interactions and classroom experiences. Only some of the staff participants had a primary job responsibility connected to STEM students, but all of the staff participants interacted with STEM students in some capacity, such as in University-wide roles that reached all students.

For staff stakeholders, the team followed the same method used for faculty stakeholders: face-to-face (zoom) sessions and follow-up questions in writing. The team identified a list of prospective staff members, with the goal of including staff professionals who worked in academic units, such as a college or school, as well as non-academic offices, such as athletics, student development, and the registrar. As the team did in the process of identifying prospective faculty participants, the team generated a preliminary list of prospective staff and then asked positional leaders to recommend other staff members who interacted with STEM students and STEM faculty. The team then used email to recruit the participants.

Based upon availability and interest, the team selected a total of sixteen staff members, and divided them into two cohorts of eight participants. Each staff cohort participated in one facilitated conversation around three guiding questions developed by the team. Afterward, participants offered written responses to a different set of questions. Compared to faculty participants, staff participants offered much more detail in their responses to written questions.

Like faculty, staff participants were also offered a stipend for their involvement, with the stipend contingent upon participation in the guided conversation and written responses submitted via a google form. The staff conversation was facilitated by the outside consultant, with the consultant taking notes and with no recording made of the meeting. Every effort was made to anonymize staff members' answers. However, the team determined that the perspective revealed in some comments was especially insightful, but could be tied back to an individual participant. For this reason, the consultant communicated with those staff members to ask if they wanted to retain a comment that might identify the speaker, modify the comment, or remove it altogether. Only a few staff members asked to strike or revise responses, but all very much appreciated the opportunity to revisit their responses if they wanted.

Results

The team framed its engagement with stakeholders as a series of learning exercises (***see***): learning what students thought about their education and what/where the University could do better; learning what faculty, staff, and students thought were barriers to success; learning about faculty attitudes toward student success and DEI; learning how staff members viewed their relationship to the learning process; and other concerns. The team also drew from institutional data related to course enrollment, grades, demographic information, etc. Guided by their analysis of these many data points, the team decided how to interpret, and frame the barriers to effective STEM education (***judge***). The value of the intersectional approach used in this study can be readily demonstrated by overlaps in observations among stakeholder groups that allowed the self-study team to explore many facets of belonging and inclusion as reported by STEM and former STEM students, staff professionals, and faculty. Findings demonstrated that the institution's STEM learning barriers involve both so-called academic and non-academic factors; of course, there is some overlap between them. Below is a selection of those findings.

Academic Barriers

Here, academic barriers are closely related to what happens in the classroom and in related co-curricular activities, such as mentored research. Examples of academic barriers included the following.

Non-inclusive learning environments. The team found stark evidence that that the STEM learning environment is not inclusive: students from different population groups have vastly different academic outcomes (e.g., course performance, retention, and graduation), with UR/US students faring much worse than non-UR/US students. To put this bluntly, the learning environment was benefitting some students and disadvantaging others, and this must be mitigated. Of course, disparities are a common problem in higher education, but the self-study helped to drill down into specific gaps.

Differing access to mentored research. Students from different demographic groups have inequitable degrees of access to, and participation, in mentored research experiences, which are a hallmark of the University's undergraduate education and a widely recognized high impact practice [23]. This is partly a matter of funding availability, and partly a matter of networking. But, regardless of the reason, uneven access to mentored research has a direct impact on student's degree progression, path to graduate school, and future employment.

Differing experiences of belonging and self-efficacy. STEM students and staff professionals also reported very different perspectives in terms of feelings of belonging and self-efficacy within classes, within social settings, and when students engage with professors and peers. Faculty from UR/US groups also complained of behaviors from peers and students that diminished their sense of belonging. Students and staff were especially vocal in arguing that the University needs to hire more diverse faculty, so that students could identify with, and "see themselves" in the faculty. As noted below, one research study showed that whereas both men and women at a university earned low grades in STEM, women were more likely to drop out as result.

Faculty attitudes toward STEM students. The "student deficit" mindset is alive and well among many STEM faculty who declare that their students would have better learning outcomes, with fewer DFWs, if the University simply admitted more qualified students. Faculty sometimes see a student's failure to succeed in a STEM class as a learning experience that helps nudge them to find a more major outside of STEM, and students reported that some professors hastily counseled them to leave a STEM major following a poor grade on an exam (what one student called a "weed out culture."). This truly matters for diversity and retention in STEM: one study found that women were more likely leave STEM due to poor grades than their male peers [24]. At this University, some students entered STEM with enthusiasm, but loss interest as a result of negative faculty experiences. Students sometimes shared these experiences with staff support personnel who participated in this study, but those staff had no path for addressing concerns that did not rise to the level of a formal complaint.

Large class sizes. Large classes are known to pose challenges for STEM students [25]. In this self-study, stakeholders from different groups consistently reported that large, introductory classes had a negative impact on student learning, but one of the reasons was a surprise:

inequities in peer support. The large classroom environment tended to discourage students from asking questions in class or developing a relationship with the professor. Instead, the students relied on peers for support, and students of color reported feeling socially isolated and excluded from study groups. Faculty complained that large classes indeed prevented them from forming relationships with students, with negative implications for seeking out future research assistants.

Barriers at the Institution Level (Processes, Infrastructure, Climate)

The intersectional approach embodied by seeking the voices of STEM students, faculty, and staff helped to identify deeply rooted structural and climate barriers at the institutional level. As noted above, these are not the type of school-level factors that research studies typically address on STEM student success. In some cases, a student could name a problem (e.g., "I have trouble getting the classes I need" or "I couldn't do an internship") without realizing what they are experiencing is, in fact, an institutional barrier. Examples of barriers that were readily identified by multiple stakeholder groups included the following.

Advising holds and advising privileges. Financial holds, for example, can derail a student's course selection and degree programs for their entire undergraduate program because it delays their registration. Like many universities, the University in this study offers advance registration and advising to privileged groups, especially honors students and athletes, which acts as a barrier to other students who must register later. But, individual students do not see this as a systems problem.

Financial barriers to internships and experiential learning. Experiential learning is a hallmark of the University's undergraduate education, but access is very unevenly distributed among students, with UR/US students reporting more barriers to access—such as the need for easy transportation to get to an internship or project site, and the inability to take do co-curricular activities that are unpaid or after typical class hours, when they need to work. Uneven funding across schools and majors contributes to these barriers, making this an institutional barrier.

Advising. This study treated advising as an institutional matter, and not as an "academic" matter because it happens outside of the formal learning environment. Faculty offered perspectives on the burdens of advising, such as too many advisees without enough administrative support and training. Staff saw the urgent need for more, better trained advisors, whereas students described bad advising or advising that simply was ineffective. All groups argued for more advising support, and faculty and staff specifically asked for more financial resources for advising. However, investments in advising can be hard to justify, because the true impact of any particular change in advising is very hard to measure.

IT structures and student support offices. Some offices on campus seem to have built-in systems and processes that have a disproportionate impact on UR/US STEM students, especially with regard to advising, course registration, and navigating degree requirements. These systems disadvantage students from UR/US groups, in part because some of the systems are expected to be self-service. Some students simply give up when they cannot navigate a system. Students who know how to navigate University systems, or know how to ask for help, have an advantage.

These systems put faculty and staff in the position of trying to work within, or defend, systems that have inequities built into them.

Housing. The University has a stock of highly coveted houses for undergraduate students. To address demand and to promote socio-cultural engagement, the University instituted a points system in which students can earn housing points for participating in campus activities, events, lectures, etc. Students with more points get earlier slots for housing selection, but students in our study complained that the system actually hampered their GPA, i.e., they would forego studying or time relaxing with friends to accumulate points, or that students with more resources (e.g., no need to work) could take advantage of more point-eligible opportunities. Faculty tend to be unaware of these concerns when they design and schedule point-eligible activities. Staff observed that housing played a major role in student success and belonging. Fierce competition for housing points only added stress for students who need strong social support, especially those from UR/US backgrounds.

Conclusion

None of the self-study's findings were earth shattering and the University's problems are not unique within higher education. But, the team did uncover complex barriers that cannot be solved with simplistic solutions. If UR/US students are experiencing disproportionate DFW rates in particular STEM classes, then the University is obliged to examine all of the factors that may be at work: the quality of the teaching, faculty attitudes, the students' preparation and what they need to develop as learners, social support mechanisms around the students, etc.

To date, the self-study team has produced a wealth of recommendations, and the University has begun to address or implement some of them in ways that are meaningful and address root causes (***act***). However, while the particular findings of this self-study are important to the University sponsoring the work, what is especially important about this research is that it argues for the feasibility and value of a multi-level study to improve STEM learning environments across an institution of higher learning. This study considered everything from gateway courses to housing to undergraduate research opportunities to climate. What is most significant is that the team used stakeholder concerns and stakeholder voices to illuminate the depth and complexity of perceived barriers to STEM student success, and to ensure that any proposed interventions would be appropriate.

Finally, what is also relevant is that in its wide-ranging work, the team began by defining STEM student success for all students and then using an intersectional approach to understand what is standing in the way. They committing to using an equity lens—especially with regard to race and gender—to openly discuss inequities and barriers to success when they were uncovered. Addressing consistently poor student outcomes (e.g., DFW rates, low retention in STEM, etc.) in key classes or disciplines is neither an infringement on a faculty member's academic freedom nor a diminishment of disciplinary rigor. Rather, consistently poor student performance is a strong signal of systems failures. And systems failures require systems solutions.

Availability of data

The most important data from this study are the data collection and survey instruments used with each stakeholder group. These are available by request from the study's authors.

References

[1] J.P. Martin, K.S. Stefl, L. W. Cain, and A. L. Pfirman, "Understanding first-generation undergraduate engineering students' entry and persistence through social capital theory." *International Journal of STEM Education* vol. 7, pp. 1-22, 2020.
[2] M.N. Miriti, "The elephant in the room: race and STEM diversity," *BioScience* vol. 70, no. 3, 237-242, 2020.
[3] B.P. Koester, G. Grom, and T.A. McKay, "Patterns of gendered performance difference in introductory STEM courses." *arXiv preprint arXiv:1608.07565*, 2016 [Accessed August 15, 2024].
[4] A. Malespina and C. Singh, "Gender gaps in grades versus grade penalties: Why grade anomalies may be more detrimental for women aspiring for careers in biological sciences," *International Journal of STEM Education* vol. 10, no. 1, pp. 1-11, 2023.
[5] M. Babeş-Vroman, T. N. Nguyen, and T.D. Nguyen, "Gender Diversity in Computer Science at a Large Public R1 Research University: Reporting on a Self-study," *ACM Transactions on Computing Education (TOCE)* 22, no. 2, pp. 1-31, 2021.
[6] E.M. Bensimon, "The misbegotten URM as a data point," *Los Angeles, CA: Center for Urban Education, Rossier School of Education, University of Southern California*, 2016.
[7] H.A. Bhatti, "Toward "inclusifying" the underrepresented minority in STEM education research," *Journal of Microbiology & Biology Education*, vol. 22, no. 3, e00202-21, 2021.
[8] D.J. Asai, "Race matters," *Cell*, vol. 181, no. 4, pp. 754-757, 2020.
[9] A.G. Enriquez, C.B. Lipe, and B. Price, "Enhancing the success of minority STEM students by providing financial, academic, social, and cultural capital," In *ASEE annual conference & exposition*, vol. 2014, 2017.
[10] G.H. Kuh, J.K. Kinzie, J.A. Buckley, B.K. Bridges, and J.C. Hayek, J. C. "What matters to student success: A review of the literature. In *commissioned report for the national symposium on postsecondary student success*, National Postsecondary Education Cooperative, 2006. Available: https://nces.ed.gov/npec/pdf/Kuh_Team_Report.pdf
[11] J.J. Fry, "Reframing the deficit mindset: first-generation students and concurrent enrollment," Ph.D. dissertation, University of Texas, Austin, TX, 2020.
[12] G. Menezes, C. Bowen, J. Dong, L. Thompson, N. Warter-Perez, S. Heubach, D. Galván, J. Mijares, E. Schiorring, and E. Allen, "Eco-STEM: Transforming STEM Education using an Assetbased Ecosystem Model," in *2022 ASEE Annual Conference, Excellence Through Diversity*, Minneapolis, MN, June 26-29, 2022.
[13] X. Wang, D. Minhao, and R. Mathis, "The influences of student-and school-level factors on engineering undergraduate student success outcomes: A multi-level multi-school study," *International Journal of STEM Education* vol. 9, no. 1, 23, 2022.
[14] A. Kezar and E. Holcombe, "The role of collaboration in integrated programs aimed at supporting underrepresented student success in STEM," *American Behavioral Scientist* vol. 64, no. 3, pp. 325-248, 2020.

[15] T.B. McNair, E. M. Bensimon, and L. Malcom-Piqueux, *From equity talk to equity walk: Expanding practitioner knowledge for racial justice in higher education*. Hoboken, NJ: John Wiley & Sons, 2020.
[16] Thomas Aquinas, *Summa theologiae*, II-II, q. 47.
[17] A.M. Mealey, P. Jarvis, J. Doherty, and J. Fook, eds, *Everyday social justice and citizenship: Perspectives for the 21st century*. Oxfordshire, UK: Routledge, 2017.
[18] S.L. Rodriguez and J. M. Blaney, "We're the unicorns in STEM": Understanding how academic and social experiences influence sense of belonging for Latina undergraduate students," *Journal of Diversity in Higher Education* vol. 14, no. 3, 441-455, 2021.
[19] A. H. Master and A. N. Meltzoff, "Cultural stereotypes and sense of belonging contribute to gender gaps in STEM," *Grantee Submission* 12, no. 1, 152-198, 2020.
[20] M.T.V. Taningco, "Latinos in STEM professions: Understanding challenges and ppportunities for next steps. A Qualitative study using stakeholder interviews," *Tomas Rivera Policy Institute*, 2008.
[21] https://www.heri.ucla.edu/PDFs/surveyAdmin/fac/Listing-of-STEM-Disciplines.pdf [Accessed August 1, 2024].
[22] K. Charmaz, "Grounded theory," *Qualitative psychology: A practical guide to research methods*, vol. 3, pp. 53-84, 2015.
[23] G. D. Kuh, and J. Kinzie, "What really makes a "high-impact" practice high impact," *Inside Higher Ed,* April 30, 2018. Available: https://www.insidehighered.com/views/2018/05/01/kuh-and-kinzie-respond-essay-questioning-high-impact-practices-opinion. [Accessed August 1, 2024].
[24] C. J. Ballen, S. M. Aguillon, R. Brunelli, A.G. Drake, D. Wassenberg, S.L. Weiss, K. R. Zamudio, and S. Cotner, "Do small classes in higher education reduce performance gaps in STEM?" *BioScience* vol. 68, no. 8, pp. 593-600, 2018.
[25] E. Kara, M. Tonin, and M. Vlassopoulos, "Class size effects in higher education: Differences across STEM and non-STEM fields," *Economics of Education Review* vol. 82, 2021. [Online.] Available: https://www.sciencedirect.com/science/article/pii/S0272775721000236. [Accessed August 1, 2024].