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Effective Practices and Lessons Learned in Managing and Sustaining Curriculum and Cultural Change at CEEatGT

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Abstract

A research-intensive school of Civil and Environmental Engineering embarked on a change journey some years ago to enhance early engagement in the profession and major, augment retention and improve engineering efficacy in the undergraduate program. The initiative aims to enhance the sense of belonging of the students to the profession, school, and major, as well as to graduate more holistic engineers with an entrepreneurial mindset. Subsequently garnering external funding, the initiative applies interactive learning and entrepreneurially minded learning (EML) pedagogies - such as problem-based learning (PBL), team development, story-driven learning (SDL), and, value sensitive design (VSD) as well as computational skills development - to engage students early and keep them engaged throughout their undergraduate journey. This paper discusses effective practices, challenges and lessons learned along the way with the objective of supporting other change journeys in undergraduate engineering education. A wide range of practices were identified to be effective including developing the initiative around one or more real, compelling problem(s), engaging stakeholders on a continuing basis to communicate motives for change; managing tensions and sharing successes; investing in faculty and staff development to support the desired changes; asking students to share their stories with the broader community highlighting benefits from the initiative; institutionalizing the change objectives in formal plans, programs, policies, and positions within the school, and formally evaluating the impacts of the change(s), and sharing and rewarding successes. This paper aims to contribute to the growing body of knowledge on effective practices for change in undergraduate engineering curricula and programs.

Keywords: Change Management, Curriculum, Cultural Change, Sustainability

Introduction and Objectives

In 2018, the Associate Chair for Undergraduate Programs in the School of Civil & Environmental Engineering (CEE) at the Georgia Institute of Technology conducted a Sankey diagram analysis to understand student change of majors in and out of the undergraduate programs. This analysis showed that about half of the students who initially declared Civil Engineering (CE) or Environmental Engineering (EnvE) as majors were changing majors out of the CEE programs in their first two years at the Institute. At the same time, approximately the same number of students changed majors into the CEE programs (most commonly from other engineering majors). The school's leadership hypothesized that undergraduates were transferring out of the CEE programs because there were few courses to engage them in the subject of Civil Engineering or Environmental Engineering as they fulfilled their core requirements (i.e., math, basic sciences, and general ed courses) during their first two years of study. This represented a missed opportunity to enhance their sense of belonging to the profession and the program; to enhance their professional identity development, and to help them develop a stake in the CEE programs [1]. The leadership team also perceived an opportunity to strengthen computational skills, such as applying data analytics, artificial intelligence including

machine learning, and other computational approaches in a technical and problem-based context. There was emerging evidence that engineering students are increasingly attracted to engineering programs that have significant opportunities for computational skills development around real-world problem solving [2], [3], and that programs with a heavy emphasis on real-world problem-solving tend to create more significant impacts for women and racial minorities [4], [5], [6].

Sometimes referred to as "the desert" in engineering education circles, the dearth of engineering coursework in the first two years of engineering programs is not uncommon in undergraduate engineering programs around the country as students take courses outside engineering departments to fulfill their core requirements and in preparation for their major courses. Over the past decade, several CEE programs around the country have embarked on informal and formal efforts to transform this "desert" in their programs. In our school, (we use the term "school" for an academic unit that is referred to as "department" in many institutions of higher learning), two faculty members - including the Associate Chair for Undergraduate Programs - took the initiative in 2018 to develop a first-year CEE course to introduce our undergraduate students formally to Civil and Environmental Engineering during their first year in the program. A year later, the Associate Chair for Global Engineering Leadership and Entrepreneurship, working with the School Chair and Associate Chair for Undergraduate Programs, colleagues in the Department of Biomedical Engineering, a host of colleagues in the school, and other CEE programs around the country, developed grant proposals to formalize and extend these ongoing efforts to enhance CEE undergraduate education.

In 2020 and 2021, the National Science Foundation (NSF) and the Kern Entrepreneurial Engineering Network (KEEN) funded initiatives to develop more holistic engineers with entrepreneurial mindset aligned with the overarching goals of the CEE programs to enhance undergraduate student sense of belonging to the profession and major, enhance retention, and augment engineering efficacy. These funded initiatives further formalized CEE's efforts to expand existing capabilities for the desired change; it made available the expertise and advice of a change specialist from the Scheller College of Business, and provided a Learning Scientist who would lead faculty development initiatives to enable the desired change. With a robust network of support, we have attended numerous trainings, implemented several innovations, conducted ample reevaluations, and have now begun to see the impacts of our efforts.

This paper discusses practical approaches we have found effective in navigating such change in an undergraduate engineering program. First, we describe the key change frameworks and principles we presented in the grant proposals and garnered from an early faculty development series in the two formal initiatives. Then, we present fifteen practical approaches - some of which came with significant milestones - that we found to be effective, and discuss how they helped us take advantage of existing opportunities or overcome existing challenges or constraints. Finally, we reflect on some of the most significant keys for managing change effectively in undergraduate STEM education - based on our experiences as we have enhanced undergraduate engineering education for future civil and environmental engineers and leaders.

Change – Three Conceptual Constructs

Three conceptual frameworks on change have framed our journey with our focus shifting across and sometimes beyond these frameworks over time. We presented Borrego and Henderson's (2014) *Multiple Categories of Change Strategies* framework [7] as the foundational framework for change in our professional formation experience (PFE) application to the National Science Foundation's (NSF) Revolutionizing Engineering Departments (RED) program. The mapping of change theories relevant to STEM higher education settings encourages change agents to consider change from a great diversity of perspectives in order to design more robust change efforts (*Figure 1*). As reported in [8], another group developed similar categories through an independent and timeframe-overlapping review of the literature, suggesting that the criteria are replicable for change in undergraduate STEM contexts. Borrego and Henderson [7] concluded that robust change is most likely to take place when multiple change strategies are employed across the four dimensions shown in Figure 1. We proposed to apply this framework to foster robust change in the school in order to achieve three main objectives: (1) develop pedagogy; (2) implement and evaluate pedagogy, and, (3) shift culture to sustain the innovations [9]. Figure 1 shows the varied strategies intended to achieve these three objectives.

Figure 1: Multiple Strategies Change Model [7] applied in CEE RED grant proposal ([9] (PDL: Problem-Driven Learning, WPE: Whole Person Education, SAFE: State Authenticity as Fit to Environment) [10].

We included a change expert as co-principal investigator on the RED team, a professor in the Scheller College of Business, who was Director of the Institute of Leadership and Entrepreneurship, since renamed the Institute of Leadership and Social Impact (ILSI). ILSI is an interdisciplinary unit that develops individual and organizational leadership capabilities for economic growth, social responsibility, and environmental sustainability. With a focus on organizational behavior, our change expert has studied people-related issues including leadership, change management, and culture and innovation. This change expert participated in an early faculty development series to help equip our team with effective change management capabilities.

Early in our faculty development seminar series, our change expert asked us to identify actual and potential areas of tension in the RED initiative, and introduced us to the Polarity Thinking

Framework to manage these tensions [11]. Examples of areas of tension that surfaced in the early period of the initiative included concerns that (1) the proposed change(s) would lead to undesirable changes in breadth versus depth of curriculum content, and (2) stressing of professional skills versus engineering skills would lead to less (rather than more) rigor in the curriculum. The perception that including professional skills development as an integrated part of engineering courses would reduce the rigor of the curriculum was a notion that underlay and would continue to underlie several discussions during the change process. Another area of concern was the potential elimination of a faculty member's course (most of them valued and long lived) to make way for new courses being proposed. There was also a growing sense of inclusion/exclusion due to the two formal and major RED and KEEN engineering education initiatives. The perception that some faculty members were "in" and other faculty members were "out" of these initiatives was another complexity that would require effective management in the coming months and years. (The "out" group included those who felt they did not have a voice in the process as well as those who did not care to have a voice.) Our change expert emphasized that polarities are things to be managed rather than problems to be solved; they are two parts of the same whole and our objective would be to guide the organization to recognize, respect, and draw from the best of both worlds. We learned that our goal was to leverage the strengths of these polarities by leaning gently into both. Polarity thinking would come to be a repeatedly useful construct as we advanced both formal initiatives.

Two tools in Williams' *Change Maker's Toolkit* [12] for making changes in STEM education were helpful for negotiating specific challenges in curriculum change during the fourth year of the initiatives, where our focus was primarily on successfully adopting two new courses in the curriculum and requiring them for all undergraduate students. "When Change Means Loss" and "Change and Stories" were particularly helpful components of the Change Maker's Toolkit, applied together with Polarity Thinking and Borrego and Henderson's Multiple Categories of Change Strategies Framework [7]. The Toolkit element "When Change Means Loss" offers strategies to engage those impacted by the change who may be feeling that there is a loss of perceived valuable elements of a highly respected, regarded and well-ranked program, in our case. Over two years earlier, the change expert had drawn our attention to the "notable lack of a platform for change" as our School of Civil and Environmental Engineering was the top-ranking undergraduate program in Civil Engineering for the first time in its 123-year history (according to the U.S. News and World Report rankings). This was the same year we received external support for our change initiative. The Toolkit offered practical ways to engage effectively with faculty who might be experiencing feelings of loss associated with the curriculum and cultural change initiative. In the "Change and Stories" element, Williams presents stories as a powerful tool to communicate the value created by the change within a school. We found that being able to tell a good story about the benefits associated with the change - especially, including student testimony or data - while not denying, but rather acknowledging and managing the risks associated with the change, can go a long way in developing buy-in for advancing the curriculum and cultural change.

These conceptual frameworks have served as a foundation for various members of the core RED/KEEN team as we have pursued curriculum and cultural change within our school. They

have been important resources that we have remembered (and momentarily forgotten!) at various times for different challenges, tasks, and activities. As Borrego and Henderson's Multiple Strategies change model [7] was used in structuring the RED initiative from its inception, it has undergirded our change initiative more consistently since the beginning of the initiative and most the changes that the school has made fall into one of the four framework categories as shown in Figure 2 below (objectives included to enable cross-referencing between strategies and objectives). Figure 2 expounds on and extends Figure 1 to highlight the actual changes made in the curriculum and the school.

Aspect to be changed (vertical axis: Individuals → Structures)

I. Disseminating: CURRICULUM AND PEDAGOGY
- Exploring CEE (CEE 1090) 1st-year course required in the curriculum.
- CEE Systems (CEE 2090) moved to 2nd year to make room for 3rd-year course.
- Data Analytics (CEE 3090) piloted and adopted as required 3rd-year course.
- Capstone Design (CEE 4090) 4th-year course leverages knowledge, skills and mindset development in CEE 1090, 2090 and 3090.
- Vertically integrated program of PBL, team, communication and computational development, and reflective learning integrates the courses at increasing levels of maturity.

II. Developing: REFLECTIVE TEACHERS

Faculty who participated in course transformation teams and engaged in the delivery of transformed courses have become more reflective teachers, more focused on designing effective teaching and learning environments supported by faculty development on effective and evidence-based practices.

III. Enacting: NEW STRUCTURES/POLICIES
- Curriculum has been modified to require more interactive teaching and learning, and to develop inclusive teaming, reflection, and computational skills in a spine of four required courses.
- CEE Strategic Plan includes key RED and EML objectives.
- Workload model and course schedule have been modified to support faculty engagement in vertical spine of courses.

IV. Developing: SHARED VISION
- Professional Formation Experience)PFE_ climate study, PFE Retreat, course transformation teams, faculty development on interactive teaching and learning, problem-driven learning, inclusive teaming and reflection, calls for proposals for course innovation, CEE education vision in strategic plan, and education innovation award – all contribute to fostering a shared vision for our educational mission.

Prescribed — Emergent

Intended Outcomes

Figure 2: CEE – Curriculum and cultural change through the lens of Borrego and Henderson's [7] Multiple Strategies Change Framework

Strategies That Have Made a Difference in our Change Journey
Our journey to achieving the primary objectives of the RED and KEEN initiatives has been a complex one with successes, challenges and lessons learned. Below, we highlight fifteen strategies that have been important, some of which will continue to be important as we transition from the formal initiatives to sustaining the changes beyond the grants.

1. *Identify a real problem or opportunity that aligns with the school's values as the primary motivation for change.* Our change initiative was built around retention of 1st- and 2nd-year students. In 2018, a Sankey Diagram analysis revealed that about half of the 1st- and 2nd-year students whose major was CE or EnvE were transferring to other majors. During the 2021-22 academic year, the school underwent a comprehensive academic program review by a team of academic and industry leaders. One of the key recommendations by the team reflected a deep concern about undergraduate enrollment and retention, stating the following: "The weak student enrollments at the undergraduate level are a serious, existential threat that requires immediate and bold action by all the program leadership." Such a statement from an external panel of experts, coupled with internal data-driven discussions, helped to convince the faculty of the presence of a real problem. Improving retention is something all constituents could rally around, the core change team has returned to time and again, and will continue to return to at various points in the journey when the faculty and project team need a reminder of the reason for pursuing this change initiative. Efforts to enhance our undergraduate students' sense of belonging to the major and profession have generally been considered worthwhile endeavors by most, if not all, faculty members in the school. This identified problem gave some faculty members reason to pause and join the search for potential solutions when they did not fully appreciate the proposed solutions or when they might otherwise have dismissed the initiative altogether. In the years following the inception of the RED and KEEN projects, we have seen an improvement in retention, compared to the baseline of 50% changing majors out of CEE, in the students taking the 1st-year course: CEE 1090: Exploring Civil and Environmental Engineering (Table 1). We have experienced the value of having an identified problem as the impetus for change.

Table 1: Number and Percentages of Students Leaving Civil Engineering (CE) and Environmental Engineering (EnvE) majors following enrollment in the 1st-year course

Year	Number of Students in CEE 1090 Course	Number of Students Leaving CE and EnvE Majors	Percentage of Students Leaving CE and EnvE Majors
2019	24	6	25%
2020	48	14	29%
2021	64	22	34%
2022	60	15	25%
2023	59	10	17%

2. *Engage, engage, engage: message the motivation for change to all stakeholders.* We began the RED and KEEN initiatives with the project leaders meeting with the full range of the school's stakeholders to present both initiatives, explain why we were pursuing them and their significance, and gather input on how best we could move forward to attain effective outcomes. The project leaders created forums to meet with our undergraduate student advisory council and all undergraduate students, our graduate student advisory council and all graduate students, our faculty, our staff, and our alumni (in the form of the school's External Advisory Board). This outreach effort was a critical factor in the overall positive advancement of the change initiative. At the same time, however, the percentage of faculty reporting that they understood the objectives of the RED and KEEN initiatives remained stubbornly low in the first two years, creeping up at a much slower rate than the project leaders desired [13], [14], [15]. The lesson we learned in these early stages of the initiatives is that continuing outreach and communication on change initiatives in engineering education is imperative for broad and substantial understanding of the initiatives.

3. *Developing a shared vision is a relatively long process and an essential one.* The importance of developing (and inspiring) a shared vision is a component of exemplary leadership and creating an alternative future is one of the Kouzes and Posner's Five Leadership Practices [16]. Just like the development of ongoing change initiatives is a process, so too, we found, is the development of a shared vision. During the first several months of the formal initiatives, leaders in the RED Consortium (REDCON) organized a focus group for several RED teams [17]. The RED Consortium is the network of NSF RED grant awardees that met on a regular basis for group mentoring in a community of practice to share evidenced-based best practices as they implement their respective RED objectives. In our focus group, our RED team found that the perceived objectives of the initiatives varied among the members. We became aware that we would have to work systematically over the coming months to develop a shared vision. Our KEEN-supported Learning Scientist subsequently hosted several faculty development events some of which dedicated time to the development of a shared vision for the curriculum and cultural change initiatives. More than two years after the formal initiatives began, we could see a shared vision beginning to come into focus. Developing a shared vision was disrupted when some of the key players in the initiative moved to other institutions, and when the COVID 19 pandemic continued to hamper initiatives. Therefore, working toward a shared vision, we learned, is something that must continue over an extended period after the project begins.

4. *Institutionalizing education objectives in a school's Strategic Plan is a vision management, implementation and sustainability tool.* Working with appropriate stakeholders to infuse the change initiative in formal business plans, programs, and processes in the school was a critical part of our journey. Under the leadership of the School Chair, who worked with the full range of the school's stakeholders – faculty, students, staff, alumni, and External Advisory Board members – the school undertook a year-and-a-half-long strategic planning exercise in which key RED and KEEN objectives were integrated in the school's five-year strategic plan. The adoption of RED and KEEN objectives in the school's strategic plan

marked the beginning of a different phase of the change initiative. If elements of such visions get adopted into a school's formal plans, programs, and processes, then they will have more authority in the eyes of all stakeholders and will be more likely to be sustainable. The strategic planning process, for example, can accelerate the development of a shared vision by garnering consensus to incorporate specific elements of one or more formal change initiatives in the strategic plan.

5. *Engage, engage, engage: aim to listen, acknowledge and manage areas of tension.* In several instances, various faculty members expressed concern that the development of a spine of courses with both engineering fundamentals (civil and environmental) and professional skills development would reduce the rigor of the curriculum. (The spine courses are four CEE courses, one in each year of study, taken by all students to develop their problem definition and solving capabilities, and to enhance key knowledge of the profession, sense of belonging to the school and profession, and professional identity development. These are highly interactive and vertically integrated problem-based learning courses.) Polarity Thinking directed us to listen and acknowledge the areas of tension around the change objectives while highlighting the benefits of both (i.e., leaning into both polarities). The words of the RED Change expert "Change leadership is about polarities to be managed" proved to be true over and over again in the first four years of the RED initiative. It is also premised on both/and possibilities rather than either/or possibilities. Engaging in arguments was a futile exercise that could further polarize the parties involved, reduce the chances of buy-in, and potentially destroy possibilities for collaborating effectively in the future. Aiming to practice polarity management led to the design of broad outreach programs to listen to faculty and other stakeholder input at key junctures in the journey and in preparation for major curriculum decisions.

6. *Implement faculty development activities to enable and facilitate change.* In the first year of the KEEN initiative, we hired a Learning Scientist who was pivotal to our curriculum-and-cultural change initiative. She developed and presented workshops to the core RED/KEEN faculty involved in the change initiative with the goals of developing a shared vision, developing knowledge about unfamiliar pedagogies – problem-based learning (PBL), story-driven learning (SDL) and other entrepreneurially-minded learning (EML) pedagogies; articulating and vertically integrating program themes across the spine courses; and assessing EML pedagogies using ABET (Accreditation Board of Engineering and Technology) criteria. We came to learn that it is essential to include faculty development that enables the proposed change. In particular, not all faculty may arrive with the knowledge, skillsets and mindsets needed to accomplish a revolutionary change.

7. *Collect data to establish the baseline and assess and share impacts of change initiative (climate study).* Seeing the results of an initial climate study of the school was a critical juncture for most of the faculty as they could observe, for the first time, data supporting various aspects of the rationale for change, and areas that might need attention in this process. An external evaluator designed and implemented a program evaluation to focus on

tracking student perceptions of the CEE climate and support structure. The evaluator then followed up the initial study with a 360-degree study of faculty, students and staff the subsequent year in order to consider the broader CEE environment, as well as faculty views of curricular and other innovations consistent with the RED objectives. These data were helpful for considering both student needs and faculty engagement in the change process. Initially, the study examined correlations between the proposed change objectives and desired program outcomes. It revealed some variation in faculty understanding of the RED project, and their relative willingness to adopt new innovations - pointing to the need to engage faculty in a participative process throughout the RED implementation process. The evaluation results were shared at the school's annual faculty retreat, opening up opportunities to engage and discuss the RED purpose and structure. In the early data, some indication of RED curricular changes on student assessment of the climate was observed in the initial cohort of students. These early results lent support to the RED objectives, which appeared to influence the faculty's general thinking about the necessity and importance of the RED initiative. Highlighting faculty concerns about implementation also allowed for open conversation and engagement in the process. Interest in the RED and the KEEN initiatives appeared to increase as evidenced – for example – by an increase in the number of faculty who attended the KEEN National Conference annually. This highlights the importance of active participation of faculty and staff in these processes and their roles in shifting school culture more comprehensively. Evaluation data to be collected in the final year of the project is designed to examine faculty and student experiences and perceptions of the changes and their impacts, including faculty interest in curricular and pedagogical innovation in engineering.

8. *Continue to emphasize areas where the proposed change aligns with fundamental values of the school*. The Data Analytics course was particularly well received at the 2023 faculty retreat, perhaps due to the quantitative nature of the course and its perceived usefulness in CEE graduates' careers. This reception was in contrast with earlier presentations regarding the RED and KEEN initiatives. Presentations of RED and KEEN updates to the general faculty in which there was no mention of, or allusion to, the technical content and rigor of the program were those that evoked in-depth discussions on the value and need for the change initiative itself. At the 2023 faculty retreat, the discussions successfully escaped polarities around depth and breadth and moved into the substance of how the curriculum change can be achieved. This observation underscored the importance of balancing breadth versus depth, qualitative with quantitative elements, and engineering knowledge/skills with professional skills development in subsequent updates of the change initiative to faculty and other stakeholders.

9. *Engage, engage, engage: share early successes*. Early successes, such as initial data from the climate study showing a nexus between the pedagogical changes being implemented and the students' perceptions of a slight positive shift in their sense of belonging to the school were well received by the general faculty. Such presentations, made by the program evaluator at annual faculty retreats, provided welcome gusts of wind that drove the

curriculum and cultural change initiative forward, if only intermittently. Such periodic positive interventions may have contributed to a gradual shift in faculty perceptions of the change initiative from one that was unnecessary and may reduce the rigor of the curriculum to one that was needed and a valuable effort in progress.

10. *Use formal plans, programs, and processes to drive, accelerate and institutionalize change as the initiative gathers momentum.* As the school's faculty began to buy into the change objectives, leadership opportunities opened to harness this buy-in to support infusion of the change objectives in formal plans, programs, and processes within the school. As more faculty members grew in their knowledge about the RED and KEEN initiatives and the potential of these programs to add value to the undergraduate curriculum, they became more willing to engage in discussions to infuse RED and KEEN objectives in formal plans and processes within the school. At the same time, they began to truly seek ways to mitigate or otherwise address perceived weaknesses in the initiatives. In our case, as change progressed, the School Chair perceived there may be sufficient buy-in to support adopting some of the primary RED and KEEN objectives in the school's five-year strategic plan. Once the faculty formally adopted RED and KEEN objectives in the education vision of the school's strategic plan, key elements of the change initiative were now mainstreamed in authoritative school documents (i.e., print materials, website) and had the backing of the faculty. The core RED/KEEN team gradually moved away from references to the RED and KEEN initiatives to references to the education vision in the school's strategic plan. This change eased some of the tensions surrounding the proposed curriculum change arising from initial concerns about preserving and enhancing CEE technical content and rigor, and improved the quality of discussions to address these concerns. Progress with the initiatives is tracked in a manner consistent with the broader strategic plan, thus becoming a key part of the school's core activities as opposed to a satellite set of activities being pursued by a subset of the school.

11. *Allocate resources to support the proposed change*. Allocating resources to enable the proposed change was crucial for success. In our case, the core RED/KEEN faculty, with invitations to the broader general faculty, participated in faculty development session on a monthly basis – led by the KEEN-supported Learning Scientist. Without this activity, the proposed changes would have been much more difficult to accomplish. In addition, CEE leadership issued annual calls for proposals for course innovation to disburse mini-grants that would support infusion of PBL and EML pedagogies such as Story-Driven Learning (SDL) and Value Sensitive Design (VSD) as well as computational skills development in undergraduate courses in the school. Finally, when another campus unit hired our Learning Scientist into a permanent position, CEE leadership decided to plan on hiring a learning scientist or education development professional to be the central point of contact responsible for executing the education objectives in the school's strategic plan.

12. *Engage, engage, engage: have those benefiting from the change tell their story*. The power of telling the story was seen over and over as students began to offer both unsolicited and solicited testimony on the pedagogical changes that were occurring in various courses. We

found sharing early and ongoing successes to be a crucial driver of change as students began to respond positively to the ongoing curriculum changes. Furthermore, giving students a platform to tell their stories empowers them and validates that they are an integral part of the change process.

13. *Build a scaffolding of support by communicating with smaller faculty groups in advance of a full faculty discussion.* Curriculum change is difficult. The curriculum change necessitated by the RED and KEEN initiatives required adopting two new courses as permanent courses within the curriculum and requiring them for all undergraduate students. This path would require removal of some existing curriculum content, a subject that made many faculty members concerned. At the beginning of the 2023-24 academic year, the Undergraduate Curriculum Committee Chair, the Associate Chair for Undergraduate Programs and the Associate Chair for Global Engineering Leadership and Entrepreneurship met to develop a plan to navigate this change and agreed on a broad faculty outreach effort that would involve visiting each of the six academic groups: Construction and Infrastructure Systems Engineering, Environmental Engineering, Geosystems Engineering, Structural Engineering, Mechanics, and Materials; Transportation Systems Engineering, and Water Resources Engineering. The outreach effort would involve presenting options for the proposed changes, listening to the faculty groups, and gathering information on their respective perspectives on curriculum needs and constraints, as well as areas where they were willing to make compromises. This critical information was used in crafting curriculum change proposals that aimed to address needs and constraints of the academic groups while advancing the overall change objectives at the school level – thereby enhancing the chances that the overall faculty body would vote to accept the proposed changes, with the sense that they would add value at both the academic group and school levels. The outreach effort to various academic groups extended over a semester-long period. Subsequently during the next semester, the Undergraduate Curriculum Committee Chair and the Associate Chair for Undergraduate Programs presented the proposals to the faculty at a monthly faculty meeting. Ensuing discussion in the faculty meeting led to some iteration on the proposals. The Undergraduate Curriculum Committee Chair and the Associate Chair for Undergraduate Programs brought the refined proposals back to the faculty during the subsequent monthly faculty meeting. The school's faculty (over 50 faculty members) voted almost unanimously to adopt the curriculum change proposals in February 2024 (with only one "no" vote for the Civil Engineering curriculum change proposals, and one "abstention" vote for the Environmental Engineering curriculum change proposals). The final recommendations were an outcome of this process of intensive engagement. The final curriculum change recommendations were an evolution from those that were initially proposed to the general faculty. Furthermore, there was support from the faculty to continue this process and assess our curriculum further, indicating that a sense of trust had been cultivated during the engagement process.

14. *Create an award to incentivize and sustain the change.* A new education innovation award has been implemented – unanimously approved by the School's Awards Committee after the project leaders had made a case based on the value it would add to the portfolio of CEE

awards. The CEE Education Innovation Award incentivizes reflective teaching and learning, supported by appropriate faculty development. The award facilitates cultural change associated with applying the best practices in engineering education – knowledge, pedagogy and mindsets – to design effective teaching and learning environments, and to make contributions to advance best practices as they evolve in the future.

15. *Mentoring is essential: engage in mentoring as mentee and mentor.* The NSF RED grant we were awarded in 2020 is an Adaptation and Innovation (A&I) grant, requiring that we partner with other academic units in mentoring relationships that facilitate effective and efficient change as well as apply proven best practices in the RED community and broader engineering education literature. In our case, we partnered with the Glenn Department of Civil Engineering at Clemson University and the Coulter Department of Biomedical Engineering at Georgia Institute of Technology. These mentoring partnerships launched us in an advanced state: we had the opportunity to learn from the successes and lessons learned by our partners. We knew some of what to avoid, had access to evidence-based effective teaching-and-learning practices as well as sounding boards for all major initiatives we considered. We also had a significant mentoring resource in the RED Consortium (REDCON). The structure of the RED A&I program and this supporting mentoring network resource helped move our project forward more rapidly from the outset. In the words of one of our mentors at our 2022 annual RED Advisory Board Meeting: "You have done in one year what it took us three years to do," – a testament to the effectiveness of the RED A&I program structure.

Concluding Remarks

Curriculum and cultural change are difficult and often require patience. The change journey has been a process in which we have grown in our knowledge and maturity about the dos and don'ts of curriculum and cultural change in STEM educational environments in general and in undergraduate engineering programs more specifically. The journey continues. What has really mattered in this process? Each of these elements and more have mattered over the past several years: having a definitive and compelling problem or challenge; the mentorship of peer programs that have successfully navigated similar changes; a strong team of colleagues committed to making the change happen in ways that respect the desires of the faculty and maximize value for the students at large; a mindset embracing the fact that change and communication are not unidirectional; a recognition that good and bad change may and will likely happen along the way (e.g., the big problem of losing key team members); and a continuing willingness to communicate, communicate, communicate and engage, engage, engage with the faculty and other stakeholders messaging the motivation for the change and the benefits it will bring. Self-encouragement and not taking things personally have also mattered, as has returning to the fundamental reasons for pursuing the change in the first place. The willingness to pivot across various change management frameworks as needed, to leave behind those that were not needed at different phases of the initiative; to convert potential conflicts into polarity management exercises; and to approach such change as a marathon rather than a sprint – these have all

mattered. As our colleagues in the engineering education community pursue change to strengthen and enhance the value of their undergraduate student experiences and the quality of their graduates, it is our hope that our experience will offer some valuable nuggets of wisdom that will both ease and accelerate the process.

Acknowledgements

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