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Eco-STEM: Transforming STEM Education using an Asset-based Ecosystem Model

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Abstract

A 2019 report from the National Academies on Minority Serving Institutions (MSIs) concluded that MSIs need to change their culture to successfully serve students with marginalized racial and/or ethnic identities. The report recommends institutional responsiveness to meet students "where they are," metaphorically, creating supportive campus environments and providing tailored academic and social support structures. In recent years, the faculty, staff, and administrators at California State University, Los Angeles have made significant efforts to enhance student success through multiple initiatives including a summer bridge program, first-year in engineering program, etc. However, it has become clear that more profound changes are needed to create a culture that meets students "where they are."

In 2020, we were awarded NSF support for Eco-STEM, an initiative designed to change a system that demands "college-ready" students into one that is "student-ready." Aimed at shifting the deficit mindset prevailing in engineering education, the Eco-STEM project embraces an asset-based ecosystem model that thinks of education as cultivation, and ideas as seeds we are planting, rather than a system of standards and quality checks. This significant paradigm and culture transformation is accomplished through:

1) The Eco-STEM Faculty Fellows' Community of Practice (CoP), which employs critically reflective dialogue[1][2] to enhance the learning environment using asset-based learner-centered instructional approaches;
2) A Leadership CoP with department chairs and program directors that guides cultural change at the department/program level;
3) A Facilitators' CoP that prepares facilitators to lead, sustain, update, and expand the Faculty and Leadership CoPs;
4) Reform of the teaching evaluation system to sustain the cultural changes.

This paper presents the progress and preliminary findings of the Eco-STEM project. During the first project year, the project team formulated the curriculum for the Faculty CoP with a focus on inclusive pedagogy, community cultural wealth, and community building, developed a classroom peer observation tool to provide formative data for teaching reflection, and designed research inquiry tools. The latter investigates the following research questions:

1) To what extent do the Eco-STEM CoPs effectively shift the mental models of participants from a factory-like model to an ecosystem model of education?
2) To what extent does this shift support an emphasis on the assets of our students, faculty, and staff members and, in turn, allow for enhanced motivation, excellence and success?
3) To what extent do new faculty assessment tools designed to provide feedback that reflects ecosystem-centric principles and values allow for individuals within the system to thrive?

In Fall 2021, the first cohort of Eco-STEM Faculty Fellows were recruited, and rich conversations and in-depth reflections in our CoP meetings indicated Fellows' positive responses to both the CoP curriculum and facilitation practices. This paper offers a work-in-progress introduction to the Eco-STEM project, including the Faculty CoP, the classroom peer observation tool, and the proposed research instruments. We hope this work will cultivate broader conversations within the engineering education research community about cultural change in engineering education and methods towards its implementation.

Background

Hispanic-Serving Institutions (HSIs) share the important mission of diversifying and growing the science, technology, engineering, and mathematics (STEM) workforce. Many STEM colleges at Very High-Hispanic Enrolling (VHHE) (i.e., greater than 50% of enrolled students) HSIs are relatively non-selective and serve a substantial proportion of students who have been underserved and under-prepared by their K-12 experiences, especially when compared to most students in Predominantly White Institutions (PWIs) or in more selective institutions [3]. In addition, at many VHHE HSIs, a significant percentage of lower division courses are taught by part-time adjuncts or other non-tenure line faculty with less academic training and less access to faculty development. A recent report from the National Academies [4] recommends seven practices and strategies that are important for *minority-serving* institutions, to ensure they are not just *minority-enrolling*. The report makes it clear that MSIs need to change their culture to successfully serve their students. The seven considerations include the need for institutional responsiveness to "meet students where they are"; supportive campus environments; and tailored academic and social supports. In recent years, Cal State Los Angeles has made significant efforts to enhance student success. The College of Engineering, Computer Science, and Technology (ECST) created many successful support programs including summer-bridge, a first-year experience program and supplementary instruction, and the ECST Teaching and Learning Academy to support faulty development [5- 8]. While there are documented successes of these student support and faculty development programs, it has also become clear that more profound change is needed to create a culture that meets students "where they are." Process and program changes have had limited scope and impact, and it is challenging to sustain grant-funded programming beyond the lifetime of the grant. To drive transformative cultural change, it is essential to promote and develop paradigm-shifting, system-level transformation. As a work-in-progress, this paper discusses the strategies and research activities under development and seeks input from the research community of the efficacy and appropriateness of the strategies adopted to create and assess an educational ecosystem.

Factory vs. Ecosystem Models

Currently, many STEM educators have a mental model of the education system as a "pipeline" or "pathway," and this "factory-like" model requires standard inputs (e.g., students should be prepared with certain knowledge and skills) to function well [9]. However, the "factory-like" model does not serve the educational needs of the increasingly diverse students at VHHE HSIs. When the educational system is viewed as an assembly line, interventions are focused on "fixing the inputs" (e.g., increase the students' preparedness) (see Figure 1), which contributes to a

prevailing deficit-based mindset. The deficit-based mindset not only hinders student growth [10], but also makes educational institutions less inclusive and teaching less rewarding for faculty.

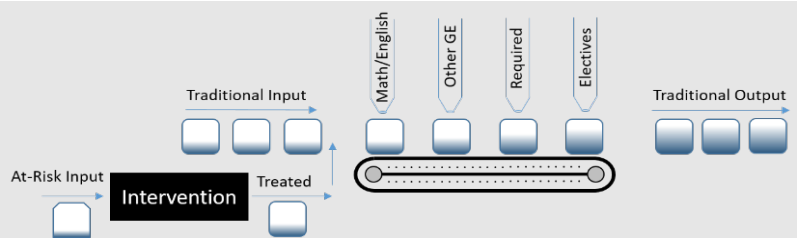

Figure 1. Traditional university "assembly line" ("factory-like") model

The lack of equity in our educational systems is increasingly being discussed in equity theory [11],[12], and the theories of community cultural wealth [13][14]. These theories suggest that we need to employ an asset-based mindset to help all students achieve success, leveraging the unique assets possessed by marginalized students that support their learning and engagement in STEM. An asset-based mindset is difficult to cultivate within a "factory-like" model, since this "assemble line-like" model requires inputs that meet a certain standard, thus requiring similar assets, which students at MSIs often do not have to the degree expected.

However, emerging research on ecosystem models [15],[16] offers a new way of thinking. In contrast to "pipelines" or "pathways," which focus on student outcomes, an ecosystem model allows us to rethink STEM education by centering it on the learning environment and the experiences that students have within the system as active agents. Our NSF-funded project, "Transforming STEM education using an asset-based ecosystem model (Eco-STEM)," uses an ecosystem as a philosophical guide (considering we are in fact a diverse ecosystem) to promote an organic and healthy environment that nurtures students, faculty, and staff to become individuals fulfilled professionally and personally. Through the ecosystem model, we begin to think of education as cultivation, and ideas as seeds we are planting, instead of a system of standards and quality checks. It is hoped that a shift in focus from production to emergence will allow all to thrive; therefore, the health of the ecosystem is measured in terms of:

1) *Climate*: Creating a supportive, inclusive, and culturally responsive learning/working environment for all members of our community;
2) *Learning Structure*: Facilitating the learning process and making teaching and learning rewarding and fulfilling experiences;
3) *Vibrancy*: Engaging in learning while emphasizing assets of our community to enhance motivation, excellence, and success.

In our Eco-STEM model, students, faculty, and staff are active agents that possess a variety of assets (and deficits). To foster a healthy environment, it is important to recognize and leverage the assets of all agents within the ecosystem. Because educational systems are in fact, ecosystems, with very diverse population of students, faculty and staff, it is hoped that the Eco-STEM model can better reflect our institutions and help us design learning strategies and policies that meet the needs of our ecoystems' agents.

The overarching goal of the project is to move from a system of colleges that demands that students be "college-ready," to a system of colleges that are themselves "student-ready." This institutional transformation will be accomplished through:

1) Shifting the mental models employed by STEM faculty from factory-like to ecosystem-like so that they will intentionally establish a healthy classroom ecosystem that facilitates learning for all students regardless of their backgrounds;
2) Changing the mental models and develop the capacity of department chairs/program coordinators so that they can lead the cultural change needed to create healthy ecosystems at the department and program levels;
3) Revising the teaching evaluation system to promote faculty development and enhance the student experience, which will help to create a healthy ecosystem at the institution.

To drive the above changes, the project will create various Eco-STEM communities, including the Eco-STEM Faculty Fellows' Community of Practice (CoP), The Leadership CoP, and The Facilitators' CoP. The Eco-STEM communities will strive to recognize, understand, and value the cultural wealth of our students, faculty, staff, administrators, as well as leverage their assets to achieve the goal of transformation.

Eco-STEM Faculty Fellows' Community of Practice

One fundamental aspect of this project is the Eco-STEM Faculty Fellows' Community of Practice (CoP). The year-long CoP supports the Faculty Fellows to develop and implement critical, participatory action research teaching (ART) projects through five half-day sessions held each semester. During the fall semester, the sessions include readings, videos, active-learning activities, and critically reflective dialogues to facilitate discussion and reflection on identity, teaching identity, community cultural wealth, teaching practice, and action research. The CoP starts with Fellows reflecting on their social and professional identities. Fellows then discuss and reflect on how their identities influence their teaching philosophy and teaching identity. Next fellows learn about the framework of community cultural wealth and reflect on how they can help students bring their whole selves into their educational environment. To support the development of their ART projects, Fellows use a newly developed resource called the Eco-STEM Peer Observation Tool to observe each other's classrooms and reflect on how they can improve their classroom/course climate, structure, and vibrancy to better support a healthy classroom ecosystem (see the next section). Fellows are also provided with additional inclusive teaching resources. Fellows propose their ART projects at the end of the fall semester and develop and implement them with support from the Eco-STEM team, the facilitators, and the other Fellows in the CoP during the spring semester. More information on the design and implementation of the Faculty Fellows' CoP is provided by Warter-Perez et al. [17].

Eco-STEM Peer Observation Tool

An effective teaching evaluation system is critical to foster faculty development and improve the student experience. As revealed by the AAUP's faculty survey on teaching evaluations in 2014 [18], both student evaluation and peer classroom observation, which are the primary tools used

for teaching evaluation in most universities, are fraught with problems in design and implementation [19]. Evidence of gender/ethnicity bias in student ratings were reported in multiples studies [20-22] . A new peer observation tool, along with a teaching and learning resource repository (http://ecostem.calstatela.edu/resources/) have been developed to help the faculty create asset-based ecosystems in their classrooms. Inspired by the Peer Review of Teaching Protocol (PRTP) [23] and the Howard Hughes Medical Institute (HHMI) Classroom Observation Protocol, the Eco-STEM Peer Observation Tool includes a list of observable behaviors related to the key indicators of a healthy ecosystem in the classroom, as shown in Table 1. Thus, the Eco-STEM Peer Observation Tool is designed to promote faculty reflection and growth.

Table 1. Key indicators of a healthy ecosystem in the classroom

Climate: supportive, inclusive, and recognizing cultural assets	**Structure**: facilitate the learning process	**Vibrancy**: activity and level of engagement
• Knows students as individuals • Encourages questions • Expresses belief in students' capacity and potential • Creates an inclusive environment	• Provides clear goals/outcomes • Class has organization & sequence • Instructional design based on knowledge of how people learn • Activities structured to develop effective learners	• Passionate about the discipline • Uses active learning properly • Dynamics between students • High level of engagement • Motivated and deep learners

More details on the Peer Observation Tool, along with other tools developed by the Eco-STEM team to support reflective faculty growth, is provided by Bowen et al. [24].

Research Objectives

The Eco-STEM project aims to address the following research questions:

1) *Changing mental models*: To what extent do the proposed communities of practice (Faculty and Leadership) effectively change mental models from a factory-like model to an ecosystem-based model of education?
2) *Asset-based success*: If the model of individual and collective activity is that of an ecosystem, to what extent does this allow for emphasis on the assets of our students, faculty, and staff and in turn allow for enhanced motivation, excellence, and success in college?
3) *Metrics for thriving*: Do new faculty assessment tools, created within the context of ecosystem feedback, allow for individuals in the system to thrive (i.e., faculty who are fulfilled and students who are learning)?

We propose that changing the mental models employed by individuals will result in cultural change (*Research Question 1*), which is based on work that concludes that the mental models we hold influence our thoughts and actions [25- 32]. It is also necessary to recognize that, although our mental models are developed through life experience and cultural indoctrination, they are not "true" or fixed, but constructed. As we begin to think in terms of the ecosystem, we see actions and ideas in a new way, which in turn expands the space of potential interventions. As we begin to see each individual as a contributor to the ecosystem, we naturally focus on assets and the need for diverse ways of thinking (*Research Question 2*). One of the indicators of a vibrant

ecosystem is the ability to sense and adjust dynamically as inputs change or as there are disruptions in the environment. The Eco-STEM team proposes use of the Eco-STEM Student Experience Survey and Peer Observation Process developed as part of this project to identify the need for systemic adjustment. The feedback will serve faculty and students alike as they work together to develop a healthy educational ecosystem.

Changing mental models: Since the mental models we use influence our thoughts and actions, we need to access the prevalent mental models employed by actors in the STEM educational ecosystem and how these change over time. We will do this through examination of the metaphors and frames [33] used in the way we talk about education. There is ample evidence that the words we use are indicators of our underlying ideas and processes (i.e., our mental models) [16-23]. We are currently developing tools to track the metaphors or references people use over time as an indicator of the change in mental models. To evaluate changes in mental models, the project will analyze faculty reflections and action research plans for metaphors [34-37]. A survey is currently being developed to identify and track changes in actors' mental models.

Asset-based success: Since *Research Question 2* requires analysis of both an increased emphasis on assets and enhanced motivation, excellence, and success in college, both qualitative and quantitative data will be used in this inquiry. To evaluate the level of focus on assets (as opposed to deficits), faculty interviews, reflections, and ART projects will be analyzed using qualitative techniques, tracking the words that faculty use to describe students or others within the ecosystem to determine if these phrases are focused on assets (the benefits individuals bring to the ecosystem) or deficits (ways the students are ill prepared for the curriculum). Quantitative analysis using surveys and traditional measures of success will also guide our analysis. As part of the project, the Eco-STEM team has developed the Educational Ecosystem Health Survey (EEHS) instrument to measure the "health" of the educational ecosystem. The Eco-STEM EEHS is comprised of constructs from several survey instruments that have already undergone statistical validation within educational contexts, many of them within higher education. The pilot results of the EEHS provide a baseline from which the Eco-STEM team will analyze diversion over the coming years of the project. Additional information on the EEHS instrument is provided by Bowen et al. [38].

Evaluation tools: Preliminary versions of the Eco-STEM Peer Observation Process, Peer Observation Tool, Resource Repository, and Student Experience Survey have been utilized by the first cohort of Faculty Fellows. Feedback is aiding the process of improving and expanding these tools. (The Peer Observation Tool and Resource Repository are publicly available here: http://ecostem.calstatela.edu/resources/.) Quantitative and qualitative research addressing *Research Question 3* will commence once sufficient progress has been made.

Discussion

Aiming at shifting the deficit mindset that is prevailing in engineering education, about a year ago, we launched the Eco-STEM project with the goal to move from an educational system that demands that students be "college-ready" to one that is "student-ready." The paper presents some

of the strategies that were implemented to create a healthy asset-based educational ecosystem. During the first year of the project, the team implemented the Eco-STEM Faculty Fellows' Community of Practice and developed the Eco-STEM Peer-Observation Tool (and supporting Resource Repository), and the EEHS. The research team has also started the development of a mental model survey. The biggest challenge so far has been to design Eco-STEM meetings, strategies, and assessment tools within the constraints of a system that evaluates and creates structures that are based on a factory-like model. Our biggest achievements so far have the devleopment of a new Peer Observation Tool for faculty, new surveys to measure the health of the ecosystem as a whole, and within classrooms, and the implemetnation of the Eco-STEM Faculty Fellow Community of Practice. Through our work-in-progress submission, we are hoping to receive feedback from peers on our work to create a healthy educational ecosystem in STEM. We also encourage those interested in the project to read the other Eco-STEM publications, which provide further details on specific strategies used by the project (i.e., [17],[24], and [38]).

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