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Linking Inclusive Narratives to Create STEM Synergy (LINCSS): A Framework for Culturally Responsive STEM Education and Engagement

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Abstract: This paper introduces a novel framework aimed at supporting non-education faculty and facilitators in creating inclusive educational programs and learning opportunities that address the needs, interests, and priorities of underrepresented individuals and communities in the field of STEM. The framework centers on the fundamental concept of understanding the learner's "why" to assist faculty in developing effective teaching strategies. The article outlines how this framework can be applied in various academic settings and contexts and provides educators and program facilitators with guidance to foster meaningful student connections.

Each element of the framework is discussed, accompanied by a set of reflective questions that encourage educators to rethink and redesign their educational experiences. The paper illustrates the practical application of the framework through three distinct case studies that include a project-based learning program for high school students, a college undergraduate STEM course, and a summer research experience for undergraduates. By employing this framework, educators and facilitators can enhance their pedagogical practices, ensuring that traditionally marginalized voices and perspectives are elevated, acknowledged, and valued within STEM education. Ultimately, this work can contribute to a more equitable and inclusive educational landscape, fostering increased engagement and success among underrepresented learners in STEM fields.

Introduction

As educational program designers for over 40 years (combined), we often get requests from faculty in other fields (esp. STEM fields) to help them with their educational activities. Embedded in the requests is how to design education programs to broaden the participation of minoritized populations in their field. We love that STEM faculty want to do this, and it has become clear that they understand the need for culturally responsive teaching and learning, but it is also starkly apparent that understanding how to do it seems intangible, intimidating, or overwhelming for many of them. In this paper, we are introducing a means to support non-education faculty and facilitators in creating educational programs and learning opportunities that elevate the contexts, interests, and priorities of individuals and communities who are underrepresented and unheard in STEM. In other words, we are introducing a way to help faculty get to the 'how' by understanding the learner's 'why.'

Creating Inclusive STEM Pathways

Despite years of calls for increasing diversity and inclusion in STEM majors and careers paths, we continue to strive to create courses, pathways, and programs that reflect culturally inclusive and engaging practices, content, and pedagogy that engages and advances Black, Latine/Latinx, Indigenous and other underrepresented students in STEM. As of 2019, 72% of US science and engineering professionals were White or Asian, 9% were Hispanic, 7% were Black, and 2% were of two or more races. (NSF, National Center for Science and Engineering Statistics, 2022). As science and technology race to address critical issues such as climate change and bio-medical challenges, diverse perspectives, priorities, and worldviews are critical. Diversifying STEM and academic pathways more broadly is a challenge that is urgent and immediate. We are guided by the following entrenched institutional and pedagogical problems supported by past research, our work with college and high school students, STEM faculty, and our own (the authors') experiences as science learners and women of color.

1. Students of color do not see themselves and their identities within specific majors and careers. (Knight et al., 2019).
2. First-generation college students need access to personally and culturally responsive information and engagement within their major and career paths (Storlie et al., 2016).
3. Many outreach, retention, and career exploration programs for underrepresented students lack realistic, relevant, and meaningful experiences and opportunities (National Academies of Sciences, Engineering, and Medicine, 2019).
4. Majors and career paths are often narrowly defined and rigidly presented. There is a need to help students explore emerging and self-created career and academic possibilities (Dewsbury et al., 2019)

Creating Inclusive STEM Narratives

The Linking Inclusive Narratives to Create STEM Synergy or the **LINCSS Framework** was created through our work with university-based STEM outreach programs, undergraduate research programs, and our partnerships with STEM faculty. The LINCSS framework is an accessible, straightforward set of five elements that can support the creation of linkages, i.e., narratives, to connect STEM to the lived experiences of students, their cultures, interests, and professional aspirations.

The five elements used in this framework *People*, *Place*, *Personnel*, *Practice*, and *Profession* are supported by work in the areas of culturally responsive teaching and learning (Gay, 2002), equity-based teaching (Valenzuela, 2016), and problem and place-based science that draws from the lives and concerns of students' lives and communities (Dos Santos, 2009; Gruenwald, 2014). There is rich scholarship about the ways educational experiences that prioritize and utilize the funds of knowledge increases engagement and connection to STEM and other topic areas (Kiyama & Rios-Aguilar, 201; González, et al., 2006). The use of place-specific and relevant community socio-scientific issues, such as environmental issues, inequities in healthcare, and so many others, has been demonstrated by Morales-Doyle (2017) and others to have transformative effects on not only individual learners but the broader community.

This framework uses the phrase "inclusive narratives" to emphasize the need to create opportunities for learners to participate in revisioning, applying, and questioning traditional STEM practices, knowledges, and science identities. In other words, we aspire to support learners in re-narrating their STEM experiences and possible futures, thus capturing the learner's 'why.' The **LINCSS framework** is a tool that can be used to design and assess curriculum, courses, and outreach programs to support culturally responsive and decolonizing educational moves across disciplines, contexts, and academic levels.

In our partnerships with STEM faculty and other practitioners, we have used this framework to help us explain and support those with little or no background in equitable teaching practices, to see the possibilities and potential linkages in their STEM content and spaces. The following paper describes how the framework can be applied in different contexts and academic settings. This framework intends to support educators and program facilitators to envision their teaching in ways that will increase student connections in whatever way they can, in whatever context they find themselves--whether it be an outdoor environmental education camp, a college chemistry course, or a research lab.

The LINCSS FRAMEWORK: The 5 P's

This framework was initially created and used in a University of Arizona for Latinx and Indigenous high school students called the Linking Southwest Heritage through Archaeology Program or LSWTHA. We used this framework to explain the goals and intentions of the program and activities to staff and guest presenters and to guide the program's overall design, goals, and evaluation. More specifically, we used the framework to create thought experiments, prompts, and an outline for youth participants to construct their own stories and counterstories during the program. With five central elements, this framework supported the development of programming and activities that created a synergy between disciplinary and domain knowledge, in this case, Archaeology, and youth's lives, cultures, and aspirations.

The LINCSS Elements

This section will explore the five LINCSS elements (Figure 1) and how we use them when partnering with STEM faculty and practitioners in various disciplines. The five LINCSS elements include 1) ***people*** (connections to specific communities/cultures), 2) ***place*** (connections to place), 3***) personal*** (beliefs and experiences), 4) ***practice*** (how knowledge is constructed and applied), and 5) ***profession/aspiration*** (future career/educational aspirations and connections). Because this framework was developed to address how to ensure the inclusion of culturally responsive approaches in educational activity design, assessment, and programmatic vision, we wanted it to be translatable to different educational contexts and STEM topics and domains. As educational program designers, we aimed to create a tool that is easy to understand, explain, and follow. In the various projects where we have used LINCSS, this framework has helped to communicate the goals and philosophies to the undergraduate and graduate staff, the STEM domain experts, and other professionals who interacted with the participants.

Embedded within each element, the educator must always frame and communicate the majors and disciplines of that field or major/discipline as tools and resources to solve and understand the needs and problems experienced by people and communities. Thus, critically opening pathways for learners to see how the major or discipline can impact their community and how they, as future experts in this major or field, can help their community.

The following section will describe each element and provide questions for re-envisioning how to design educational experiences. We then describe how the element would play out in two different applied applications: an inquiry or project-based learning setting (e.g., Research Experiences for Undergraduates (REUs), workshops, youth programs) and in a more formal learning context (classroom).

Figure 1: The LINCSS Framework

Element 1: People
Guiding Questions: How do you connect the concept, discipline, and research to real people and authentic communities? Which people and which communities?

The People element is meant to assist educators with incorporating questions that explore how their domain, concept, field, and research relate to and impacts specific people and communities.

Re-envisioning Prompts: Who will be impacted by my work/research? What do I know about the people my work will impact? What are the stories of the people my work will impact? What do they say about my work, and how does it affect them?

Inquiry/Project-based Learning: For these forms of programs or projects, faculty should encourage and provide opportunities for the learner to explore, reflect, and investigate from the lens of a culture or community. This includes focusing on problems and concerns as well as strengths and assets. This includes the histories, traditions, and conditions of these groups or individuals through time.

Curriculum design: By considering the *people* element, the instructor/facilitator is challenged to incorporate topics and concepts within cultures, communities, and traditions locally and contextualize the relationship people have and will continue to have with the topic.

Element 2: Place
Guiding Questions: How do you communicate and connect these fields/disciplines/research topics to spatial locations and ecologies? How do you connect these places to the realities and experiences of your students? Where are these places?

The place element raises questions that require us to ask how fields, disciplines, and related research questions apply to spatial locations and ecologies. Framing involves how regional and local contexts connect to particular students and are used to provide relevance to research, disciplines, and fields. Heritage can be essential in this element, encompassing an individual's geographic origins and contemporary locations. By connecting STEM learning to specific places and geographies, learners can better understand the world around them and develop a sense of place-based identity that enriches their learning experience (Gruenwald, 2014).

Re-envisioning Prompts: How does the topic/science/discipline intersect or connect to different locations or places? Do the findings of the research vary depending on where they are applied? How does place shape assumptions or understanding? How do the characteristics of a location or geography shape science and practices? Do I know the relationship between the location to the inhabitants?

Inquiry/Project-based Learning: When considering place in project-based activities, the topics and learning objectives should connect to particular places that students are familiar with. Those connections would include local and regional but can then expand to global associations. By contextualizing it to place, the student can easily relate to the role of the domain in the familiar.

Curriculum Design: In designing lessons for classroom use, like project-based learning, the student should be provided with learning activities and research opportunities relevant to the location and geographies that are meaningful and important to learners. This can be their current town, region, and places of origin for themselves or their families. There are also opportunities to connect topics to locations and places that are politically, socially, or environmentally significant.

Element 3: Personal
Guiding Question: How do students' personal, cultural, and collective experiences and knowledges connect to this topic, research, and discipline?

An individual's interests, knowledge, and personal connections situate this element as core to how a learner (student) enters acquiring new information and knowledge. The student grounds their learning around what they know, what they have lived and experienced, and how this new knowledge can help them grow as individuals with histories, heritage, and culture. This element is critical in ensuring that students' intellectual, emotional, and growth journeys embody their past as they navigate their future to a topic or discipline and towards a career.

Re-envisioning Prompts: What connections do the students have to the topic/discipline? How might I understand this topic/discipline differently by seeking the student-centered perspective? How could the students seek more answers about the topic? How do the student's personal/cultural experiences, beliefs, and values influence how they interpret my discipline and how it affects them and their community? What are ways I can provide students opportunities to question the authenticity of the research or discipline's role in helping them and their communities?

Inquiry/Project-based Learning: In the context of these types of programs, student identities must be elevated and connected to research topics and the learning experiences that are designed. Students have lived experiences encompassing their schooling, family, cultural, and geographical experiences. All of these will help them situate how to engage with a new topic in a way that makes sense to them and their current personal views. By bringing in their true selves, they can more deeply engage with the topic or discipline being introduced.

Curriculum design: As with the project-based learning context, in classroom settings, learning activities should be student-centered. Lessons and learning should be integrated to center student voices, experiences, and their funds of knowledge so that the course is meaningful and relevant to the time and the experiences they bring to the classroom. This can be done by including more reflections and learning assignments that prompt connections to their holistic identity, culture, beliefs, priorities, and experiences.

Element 4: Practice
Guiding Questions: How do you (and your field) construct knowledge and conduct research? Are you providing opportunities for your students to discuss, critique, question, and provide alternatives to these practices?

Typically, this element is the one that is featured heavily in classrooms. Practice is about skill set building, especially within a discipline or field of study. Because it is so practical, most people gravitate to this one easily. This element challenges how the domain field or discipline goes about constructing knowledge and conducting research. It is about how to do it! Framing of this component involves having students explore traditional and emerging practices within disciplines. More importantly, students should be encouraged to question, invent, and re-vision how knowledge is defined and generated in various disciplines and what and whose knowledge is attached with greater value, and why. Within this element, it is essential to introduce other forms of knowledge construction from other cultures.

Re-envisioning Prompts: What are my tools and practices? How do these tools or practices benefit communities? What alternative sources of knowledge, tools, and practices might students have experience with? How might students interpret the topic or finding differently? How are you positioning or valuing different ways of knowing in your actions, activities, and communication?

Inquiry/Project-based learning: In this context, whether in undergraduate course work or labs, field experiences, or outreach programs with youth, learners should be encouraged and supported in thinking about and experimenting with novel methods and practices of experimentation. However, as noted earlier, they should be challenged to question disciplinary practices or assumptions that lead to knowledge production. Position students as creators and provide opportunities to question and challenge accepted methods, practices, and inquiry. Bringing in other cultural and personal viewpoints to encourage creative thinking to encourage students to learn skills and create and expand scientific thinking.

Curriculum design: Within formal and informal curriculum design classroom contexts, learning should center on real-world contexts with hands-on learning experiences in the particular discipline/topic. Explicit attention to how practices of any field are embedded in particular cultural norms and systems would amplify how to be more global in their thinking, which should be a goal of any discipline striving to create innovative thinkers. Within a classroom, time is crucial, and lessons should be designed to encourage students to deconstruct and critique practices and experiment with alternatives.

Element 5: Profession
Guiding Questions: How do you communicate the professions, jobs, and majors related to this field? How do you characterize the culture, working conditions, and context of the possible careers in this discipline? Do you include explicit discussion of the skills, academic training, interests, and questions addressed by this field? How might these possible professions change in the coming years? What new jobs/professions are emerging in the coming years?

Like with the practice element, the ***profession*** challenges students to explore what the culture of the profession or discipline reveals about which identities are valued and thrive in a given field and to challenge assumptions about who can and should be included or identified with a particular career or field. In this element, we explore the myriad of possible occupations or professions within a field of study or discipline. As important, this element must capture the student pathway access routes and representation and belonging in a potential career. Students need to meet and interact with professionals in this field or discipline. It is ideal to have diverse professional representatives (e.g., BIPOC experts, researchers, scientists, and leaders) be visible and brought in for students to 'see themselves' in those roles. Learners can connect to professionals through presentations and hands-on activities (shadowing, lab, or field internships/workshops). We create inclusive environments when these professionals share their pathways, obstacles, and motivations. Finally, this element must include space to openly discuss issues of race, class, gender, and disabilities and how a profession or discipline within science is relevant to the student's identities and communities.

Re-envisioning Prompts: How could multiple experts or practitioners provide a broader view of the discipline or topic? In what ways did I include diverse role models in my program/course content? How were societal issues and challenges connected to questions taken up by my discipline/topic? How are students invited to express how this discipline and the questions it poses can impact their communities?

Inquiry/Project-based learning: Within this context, it is important to include diverse representatives of a field or discipline to share their pathways and experiences as practitioners and scientists. Opportunities should consist of involving students in authentic research experiences and demonstrations. These scientist/expert guests should be asked to see themselves as mentors and bring their authentic selves regarding their culture, ethnicity, socioeconomic status, and privileged experiences or background. By doing so, the students can better connect to them, esp. if they share similar backgrounds, but also engage with any speaker because they know how to situate where to find connections.

Curriculum design: In a classroom setting, it is so important to incorporate career information and exploration. Students need to grow their awareness of how large an array of possible careers and paths exists within any major or discipline. As with the project-based activities, references to professionals and scientists must be embedded in the course and reflect diverse cultures, ethnicities, genders, and pathways. This can be done through guest speakers, online portals with video profiles, or biosketches of folks. As important, the faculty member should share about their research and fieldwork and the individuals they interact with that make their research possible.

Applications of LINCSS: Case Studies

This section provides a brief synopsis of how we applied LINCSS to three scenarios--the original program for high school students (LSWHTA, see https://swheritage.arizona.edu/), a summer research experience, and a general education entry-level STEM course.

Case Study #1: Linking Southwest Heritage through Archaeology (LSWHTA) project

Audience:	High school Latinx and Indigenous students and high school counselors.
Discipline:	Archaeology and heritage studies
Goals:	To increase the diversity in archaeology career tracks and engagement and cultural connections to national parks and monuments and archaeology sites

Description of program: The 4-month weekend and summer high school archaeology program provides opportunities for students to visit archaeological labs and sites, allowing them to gain a deeper understanding of the significance of these locations and the various types of research conducted there. Students engaged with authentic archaeological methods, including excavation and laboratory analysis (***Practice***), and visited national parks, monuments, museums, and cultural sites in Arizona to learn about the region's history. As part of these experiences, students were exposed to multiple experts (***Profession***) in this field of study. During the program, participants had the opportunity to explore National Parks and monuments, and we encouraged them to pay close attention to the narratives presented in information pamphlets, guided tours, museum displays, and self-guided information explanation plaques. As many students were from Latinx and Indigenous backgrounds, we wanted them to bring their authentic selves and share their personal experiences tied to their people and places (***Personal, People, Place***). In doing so, they could see themselves in the stories being told at the parks because these were their ancestors (Atalay, 2006). Our goal was to provide tools for them to consider how the narratives they were hearing, or reading were being framed and from whose perspective. Thus, the program approach created an opportunity for students to explore and re-vision land ownership, assess dominant historical narratives (and whose), explore who managed heritage sites, and learn how STEM disciplinary practices and methods were used. They were also prompted to consider how they could be experts in the future and what role they could play in increasing diversity in the field. The program aimed to foster a holistic understanding of archaeology, empowering students to explore and challenge established norms while envisioning their own contributions to the field in the future.

By applying LINCCS to the program, the archaeologists involved could reframe how they talked about their field in a manner that centered the student knowledge base and their experiences. They adjusted their examples to better match the student interests, contextualized the scientific activities around shared student 'lived' experiences, and brought in guest speakers of diverse backgrounds to discuss the field and careers.

As a final product, students and counselors created digital stories to capture their full experience of this outdoor, place-based learning adventure. The stories they produced asked them to do a self-reflective analysis of what they saw and learned and to frame this within the contexts of personal and cultural identity, agency, and sustainability. In so doing, they saw themselves and their community and personal experiences as valuable in pursuing future career paths.

Case Study #2: A summer research program for underrepresented undergraduate students

Audience:	Biology and Microbiology and other STEM research-focused pathways
Discipline:	Archaeology and heritage studies
Goals:	To increase the number and likelihood of Black, Latinx, and Indigenous undergraduates persisting in biosciences and continuing to graduate school and STEM careers

Description of program: Another example of how the LINCSS model can inform the program design is the case of a summer undergraduate research program for underrepresented undergraduate students from around the country. The program was developed during COVID to address the need for research experiences despite the closure of labs. The program has continued as a fully virtual program. The program includes mentorship through participation in an authentic faculty-led biology research project, seminars, virtual meetups with fellow students and faculty, support on graduate school applications, conference presentations, and more. The LINCCS model is also used to inform the evaluation related to cultural relevancy goals and further explore how these components can create culturally sustaining research experiences and influence recruitment and retention in STEM, particularly biology disciplines.

An example of centering humans and community in this program **(*People)*** is by framing and communicating biological research as tools and resources to solve and understand the historical and contemporary needs and problems experienced by people and communities. Moderated discussion platforms and life seminars encouraged students and participating scientists to highlight people/community needs when discussing research topics and practices. Biology knowledge and research are communicated and contextualized within places or regions ***(Place*)** to create a context for research methods and the application of bioscience findings. The program encouraged guest presenters and mentors to share their personal stories, pathways, and research experiences about real-world places and contexts. This allowed students to see their own funds of knowledge, interests, and personal connections, such as their background in biology, specific research topics, and career aspirations. By making these connections, students could see the relevance of their own experiences and interests to the broader field of study, providing them with a more meaningful and engaging learning experience. ***(Personal*)**. This included reflection activities, discussion prompts, and how presenters and mentors model these personal connections through their stories and communication. Mentor resources include resources and tools on culturally centered mentoring strategies, which reflect the importance of knowing students holistically and creating connections in the relationship to biology, research, and future aspirations. Students explore traditional and emerging practices within the biology field. Students are encouraged to question, invent, and re-vision how knowledge and skills in biology are defined and generated. Due to the one-on-one mentoring research experience, students learn and enact scientific practices. In group discussions and seminars, attention is given to addressing how practices of any field are embedded in cultural norms and systems (***Practice)*.** The necessity and value of diversity in biology fields, academia, and labs are emphasized throughout the experience, and mentors and guest presenters (weekly) share their pathways, obstacles, and motivations. Race, class, and gender are openly discussed related to students' and mentors' experiences and research and career paths ***(Profession).***

Case Study #3: Entry-level science course curriculum

Audience:	Undergraduate first and second-year college students, all majors
Discipline:	Planetary Sciences and Astrobiology
Goals:	Engage, recruit, and retain more women and underrepresented college students in STEM fields, especially astronomy, astrobiology, and planetary sciences. Engage all learners and community members in space exploration and science.

Description of the program: The following example demonstrates how the LINCSS elements can be used to reimagine and enrich an entry-level astronomy course for undergraduate students. Undergraduate STEM courses requiring no prior coursework can be a pathway to STEM majors or a gatekeeper course that dissuades students from continuing in STEM-related fields or majors. One of the authors was invited to support the course level evaluation, revision, and additions to an entry-level course in Astrobiology. An added goal was to help the faculty member prepare an application for the course to become a general education course that would fulfill students' quantitative reasoning (STEM) requirements and a Humanities requirement. Using the LINCSS elements, we supported the faculty member in thinking about how each of the five elements (people, place, personal, practice, and profession) were integrated into the learning outcomes and the activities and pedagogy of the course.

The ***people*** element of the course was integrated by creating activities, assignments, and content that included and often centered on how specific cultures and countries, both contemporary and ancestral or Indigenous beliefs and practices, inform notions of space exploration and ideas about both the value and scientific emphasis related to extraterrestrial life forms, origins, and planetary and biological evolution. For example, lecture content and an interactive activity centered on researching and discussing biological evolution from a Western perspective and comparing it to the progression of avatars in the Hindu tradition. The ***people*** element was demonstrated by the student learning outcome stated in the syllabus, "Students will explore and reflect on the values, practices, and culture that have shaped their space exploration/research activities. Discussions of the personal meanings of ***place*** were explicit throughout the course as students considered their connections to place and environment and geographies beyond Earth. ***Personal*** and ***practice*** were connected to a culminating group project that asked students to design a mission and assign roles and responsibilities to each team member that reflected their aspirations, strengths, and questions. Continually integrated into the course was the question, “How do Western scientists define "life" and what that could mean for exploring the cosmos?”

As part of the program, students were encouraged to critically examine and research the assumptions inherent in the definitions of Western science. They were prompted to compare these assumptions with their own worldviews, religious traditions, and ideas held by diverse cultures. This exercise aimed to foster a deeper understanding of the cultural context in which science operates and encourage students to consider how different perspectives and belief systems may shape scientific interpretations and practices. By engaging in this thought-provoking exercise, students were encouraged to develop a more nuanced and inclusive understanding of science and its relationship with various cultural and philosophical perspectives. A learning outcome for the course was "Students will connect, critique, and reflect on cultural origins concepts and modern-day scientific approaches." Lastly, content, speakers, and the group project included the ***profession*** element by centering the many roles, disciplines, and career paths involved in undertaking space missions, scientific analysis, and public policy and societal implications of space science and exploration. The faculty member and one of the authors continue using the LINCSS model to identify existing and potential links to the five elements through pre- and post-student surveys, ethnographic analysis of student discussions and products, and course content.

Conclusion

We hope this framework can provide an entry point and ideas for advisors, faculty members, and program developers committed to creating culturally responsive programs and experiences for youth and college students, specifically those underrepresented in academia and STEM majors. Table 1 (LINCSS Elements: Three common STEM touchpoints) suggests how each of the five LINCSS elements can be embedded in various STEM programming and activities.

Much has been written about how youth can prepare for college and careers and the programmatic strategies for recruiting and retaining students in STEM and other fields that reflect low participation by black and brown students. STEM majors and career paths are often introduced and taught to students in ways that limit agency and relevancy to minoritized and other UR youth and students. As a result, students in the early stages of their academic journey lack opportunities to explore, challenge, and create meaningful visions and connections to different majors and fields. This is especially true for first-generation college students who often do not have exposure to various careers and major possibilities through generational college exposure. The LINCSS framework provides five elements that, when integrated into courses, programs, and experiential experiences, encourage students to expand their visions and push through disciplinary boundaries to create meaningful career and academic paths that reflect their cultural knowledge and connections as well as their personal goals and visions for themselves and their communities. This framework focuses on content linkages that support inclusive STEM narratives in education. The transformation of teaching and learning in STEM will need to include transformative pedagogical and structural shifts. For a discussion of these ideas, we recommend Garcia's (2023), Transforming Hispanic Serving Institutions, specifically Chapter 4, which broadly discusses liberatory pedagogy and its implications for HSIs and education.

We continue to work collaboratively with outreach programs and STEM faculty to expand the applications of the LINCSS framework, gather and analyze more robust outcome data, and document how faculty apply the framework. Our goal is to promote STEM education practices that center culturally responsive learning design across all disciplines and levels of education.

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