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Applying an Entrepreneurial Mindset to Course-based Undergraduate Research Experiences in STEM

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Course-based Undergraduate Research Experiences (CURE) can provide every student in the classroom with an authentic learning experience. The Cultivating a Culture of Entrepreneurial Mindset and Undergraduate Research (CEMUR) project at California State University, Chico (Chico State), funded by a grant from the National Science Foundation (NSF) Improving Undergraduate STEM Education: Hispanic-Serving Institutions program, created the CURE-e, which combines CUREs with developing an entrepreneurial mindset (EM) to enhance connections between scientific inquiry and solving real-world problems with the hope of engaging students in lower-division stem courses and improving persistence and retention especially with under-represented groups. A summer week-long training program for faculty from the university's three STEM-based colleges was developed that focuses on teaching the CURE model as well as developing the entrepreneurial mindset. Faculty redesign learning outcomes and syllabi that focus on a research goal as well as identify a customer or potential innovation that has broad interest and value. The first year was a pilot introduction with three faculty from three different disciplines, mathematics, computer science, and biology. Each implemented the CURE-e with their own unique approach appropriate to what research is in their own areas. The second-year cohort included 10 faculty participants. Data is just beginning to be analyzed, but preliminary results indicate students are better engaged and have a stronger science identity. Students also better understand what research is and that they are doing it. They also recognize elements of the entrepreneurial mindset and what qualities and characteristics they can develop that helps them persevere and succeed.

Introduction

In looking at the next generation of college graduates, the workforce is drastically different than it was only twenty years ago. Almost half of the workforce will be freelance by 2027 [1] and over 65% of the jobs today did not exist 25 years ago [2]. The need to be flexible, think broadly, identify opportunities, be creative and innovative are requirements of almost any profession now and into the future [3] and [4]. U.S. Bureau of Labor and Statistics projects 10.5% growth in STEM fields from 2020 to 2030 [5]. However, under-represented groups remain under-represented in STEM fields especially in engineering. A Pew Research Center study showed Black and Hispanic workers represent 9% and 8% of the STEM workforce compared to their share of all employed U.S. adults of 11% and 17%, respectively. Whereas White workers are overrepresented in STEM holding 67% of STEM jobs relative to a 63% overall share of the U.S. workforce [6]. As problems become more complex, the need to develop creative and lasting solutions will require engaging our entire diverse population. Solutions are always better with varied and diverse input where assumptions are challenged, and the status quo is replaced with unique and wholistic solutions.

The goal of this work is to improve retention and persistence in STEM courses with a focus on under-represented groups by training faculty to implement course-based undergraduate research plus entrepreneurial mindset in their high enrollment, high rates of Ds, Fs, or withdraws (DFW)

courses. Course-Based Undergraduate Research Experiences have shown to improve STEM retention and science identity [7], [8], [9]. Rather than identifying a small selective number of students to work in a laboratory doing undergraduate research, the CURE model exposes an entire lecture or lecture plus lab course to research providing research experiences to all students.

EM has shown to enhance student learning through supporting individual agency and self-efficacy leading to retention and persistence in STEM fields [10]. The Network for Teaching Entrepreneurship (NFTE) defines EM as:

> *Entrepreneurial mindset is simply the way an entrepreneur thinks and acts. It's a set of characteristics, behaviors and skills that drive action. A person with an entrepreneurial mindset:*
>
> - *Recognizes an otherwise overlooked opportunity*
> - *Has the confidence to take a risk*
> - *Communicates their ideas clearly*
> - *Can not only adjust but also learn from setbacks [11].*

While NFTE's target audience is secondary school students from historically under-represented groups, first-year students attending Chico State are only slightly older. Over half of the student body at Chico State identifies as a first-generation college student and 36.3% are Hispanic/Latinx, 2.7% Black/African American, 0.4% American Indian/Alaskan Native, 0.2% Native Hawaiian/Pacific Islander, and 43.3% are White. The goal of this project was to bring research and EM skills and opportunities to lower division classes to enhance student success in STEM and to develop a stronger STEM identity especially for those that are under-represented.

Methods

This work is focused on training faculty to implement CUREs with EM elements into their large, first-year, STEM courses, a.k.a. CURE-e. To do this faculty are offered two levels of participation, tier 1 and 2. At the tier 1 level, faculty receive course release time to redesign their STEM course and are required to participate in a Summer Institute, four to six Faculty Learning Community (FLC) sessions, and a longitudinal educational research study. At the tier-2 level, faculty are compensated to attend the Summer Institute and required to attend three to five FLC sessions.

Dr. Kelly McDonald and Dr. Catherine Ishikawa from California State University, Sacramento and the SIRIUS Project (https://www.csus.edu/college/natural-sciences-mathematics/sirius/) facilitate the Summer Institute. Drs. McDonald and Ishikawa have extensive experience designing, implementing, and teaching authentic research experiences in STEM courses. The Summer Institute is a four-and-a-half-day program where faculty learn how to introduce research to first-year students and design and implement a research program in their class. Additionally, faculty get help in developing learning outcomes, syllabi language, research ideas, and are introduced to EM. Breakout sessions throughout the institute are designed to support faculty develop their CURE-e. On the last day, faculty present their CURE-e modules along with learning outcomes and their planned in-class activities or at least a rough draft.

Throughout the academic year, faculty participate in FLCs lead by the CEMUR leadership team on various topics including EM, mentoring undergraduates, assessment, and lessons learned. These meetings provide an opportunity to interact with colleagues, learn about new and innovative teaching methods, and get support or ask questions about the CURE-e.

At the end of the semester, student feedback is collected through an Institutional Review Board (IRB) approved CURE-e Assessment Report. The goal of the assessment is to measure the degree to which a student feels connected to their STEM field and if they recognize the characteristics and activities associated with being in a STEM class and developing an entrepreneurial mindset. The feedback is shared with course instructors as well as the CEMUR leadership team for review, discussion, and continuous improvement.

The CURE-e Assessment Report was developed mainly from three sources, Hanauer, Graham, and Hatfull [12], The Persistence in the Sciences (PITS) Assessment Survey, Measuring Entrepreneurial Mindset in Youth: Learnings from NFTE's Entrepreneurial Mindset Index [13], and Laboratory Classroom Assessment Survey [14]. These resources were adapted into the 58-question CURE-e Assessment Report. It is delivered through a Google Form and takes approximately 20 minutes to complete. The CEMUR leadership team provides support to introduce the assessment tool in a CURE-e course and whenever possible provides time in class to complete it.

The CURE-e Assessment Report is designed to assess whether a student feels a connection to their STEM field and if they understand the characteristics and activities one might experience in a STEM course. Example questions focusing within the five main concept areas are given in Table 1.

Table 1. Sample questions addressing student connections to STEM.

Category / Instructions	**Response Scale**	**Example Questions**
Confidence in using or learning STEM skills		
How confident are you in your abilities to function as a researcher in your specific STEM discipline? Read each task below and indicate the extent to which you are confident you can successfully complete it.	Not at all confident Not confident Neutral Confident Absolutely confident	• Use technical STEM skills (use the tools, instruments, and/or techniques of my specific STEM discipline). • Generate a research question to answer. • Provide explanations for the results of a research study.
Personal connection to STEM		
Rate yourself on the following statements regarding your sense of yourself as a STEM person who undertakes research activities.	1- Strongly disagree 2- 3- 4- 5- Strongly agree	• In general, being a STEM person is important to my self-image • I have a strong sense of belonging to the STEM community.
Connection to the STEM community		
Think of your experience with people you know in the STEM community. The STEM community	1- Strongly disagree 2- 3-	• I feel that the STEM community provides me with choices and options. • I feel understood by people in the STEM

includes faculty, researchers, professionals in the field you are preparing to enter, students in your STEM major, etc. Rate your level of agreement with each statement.	4- 5- 6- 7- Strongly agree	community. • People in the STEM community convey confidence in my ability to do well. • People in the STEM community listen to how I would like to do things.
Perceptions of how ones values align with STEM practitioners		
Please read each description and think about how much that person is like you or not like you. Select the rating that best reflects how much the person in the description is like you.	Not at all like me Not like me A little like me Somewhat like me Like me Very much like me	• A person who thinks discussing new theories and ideas among STEM professional is important. • A person who feels discovering something new in the sciences, technology, engineering & mathematics is thrilling. • To what extent do you intend to pursue a STEM-related career that may include research?
Perception of how one aligns with characteristics of the entrepreneurial mindset		
We think that there may be a relationship between success in STEM-related majors and entrepreneurial mindset. Please read each description and think about how much that person is like you or not like you. Select the rating that best reflects how much the person in the description is like you.	Not at all like me Not like me A little like me Somewhat like me Like me Very much like me	• A person who accepts uncertainty and risk when he or she thinks it may lead to a big payoff or significant learning. • A person who has a strong work ethic; who is persistent. • A person who has the ability to learn from failure as well as success, and move forward. • A person who is a good communicator and wants to collaborate with others.

To assess whether a student understands the characteristics and activities experienced in a STEM course, the following three concepts were used to generate assessment questions:

- How often did STEM characteristics occur?
- How apparent were STEM characteristics?
- What was the perceived value the entrepreneurial knowledge?

Example questions are found in Table 2.

Table 2. Exemplar questions addressing student perceptions of the characteristics and activities experienced in a STEM course.

Category	Response Scale	Example Questions
How often did STEM characteristics occur?	Never One or Two Times Monthly Weekly I Don't Know I Prefer Not to Respond	• In this course, I was encouraged to discuss elements of my investigation with classmates or instructors. • In this course, I was encouraged to reflect on what I was learning. • In this course, I was encouraged to share the problems I encountered during my investigation and seek input on how to address them.
How apparent were STEM characteristics?	Strongly Disagree Disagree Somewhat Disagree Somewhat Agree Agree Strongly Agree I Don't Know I Prefer Not to	• In this course, I was expected to generate novel results that are unknown to the instructor and that could be of interest to the broader scientific community or others outside of class. • In this course, I was expected to conduct an investigation to find something previously unknown to myself, other students, and the instructor. • In this course, I as expected to explain how my work

	Respond	has resulted in new scientific knowledge.
What was the perceived value the entrepreneurial knowledge?	Strongly Disagree Disagree Somewhat Disagree Somewhat Agree Agree Strongly Agree I Don't Know I Prefer Not to Respond	• In this course, I was given opportunities to take initiative and work through obstacles in projects independently. • In this course, I was comfortable asking questions and proposing ideas. • In this course, I increased my ability to generate ideas and create solutions to problems. • I feel like the entrepreneurial knowledge and skills I learned in this course will help me in my major and career.

Results

Eleven faculty participated in the Summer Institute, three in the pilot year and eight in the second year of the grant. The three faculty that participated in the Summer Institute in the pilot year were all tier 1, i.e. received course release time to redesign their course. Year two saw an increase in participants with three tier 1 and five tier 2 faculty. Throughout the first pilot year, as faculty were recruited for the following year, they began attending monthly FLCs. As a result, second-year faculty were exposed to CURE-e concepts earlier than the pilot year faculty. Table 3 shows the number of faculty participating in each year as well as the courses taught. One-hundred-level classes, e.g. CSCI 111, are designed for first-year students and 200-level classes, e.g. PHYS 204A, are designed for second-year students, and so on. Tier 1 members are required to teach 100 or 200-level courses that meet a minimum DFW rate of 30%.

Table 3. Courses taught in years 1 and 2 by tier.

	Tier 1	**Tier 2**
Year 1 (pilot)	CSCI 111 – Programming and Algorithms I MATH 121 – Analytic Geometry and Calculus II BIOL 162 – Principles of Cellular and Molecular Biology	N/A
Year 2	CSCI 111 – Programming and Algorithms I MATH 121 – Analytic Geometry and Calculus II PHYS 204A – Mechanics	ABUS 101 – Introduction to Agricultural Business and Economics BIOL 162 – Principles of Cellular and Molecular Biology BIOL 402 – Microbial Ecology BIOL 416 – Vertebrate Physiology BIOL 472 – Microbial Genetics CHEM 453 – Biochemistry Lab CIVL 441 LAB 01 – Transportation Engineering

The first student assessment data were collected at the end of the fall 2021 semester from all ten tier 1 and 2 courses in the Year-2 cohort. One-hundred and eighty-four students belonging to thirty-six different majors responded. One major was from the College of Business while the remaining 35 majors were from the Colleges of Natural Sciences or Engineering, Computer Science and Construction Management.

Confidence in Using or Learning STEM Skills

Seven questions were related to assessing student confidence in using or learning STEM skills. Five of the seven questions indicated that over 70% of participants were Absolutely Confident or Confident whereas the other two questions indicated that only 58% and 68% of participants were Absolutely Confident or Confident. The percent distribution of all responses to these two questions is given in Figs. 1 and 2. Respondents were stating their level of confidence to the following two statements – Using STEM literature and/or reports to guide research studies and Develop theories (ideas that integrate and coordinate results from multiple research studies).

Figure 1. Percent distribution of all responses to the level of confidence in using STEM literature or reports.

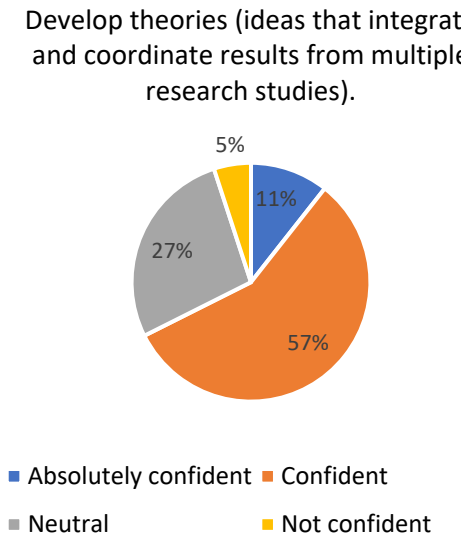

Figure 2. Percent distribution of all responses to developing theories in STEM.

Personal and Community Connections to STEM

Twelve questions were asked to assess the connection students had personally to STEM and connections they felt with the STEM community as a whole. For half of the questions, students ranked their personal and community connection to STEM at or above 70% on scales of 1 through 5, where 1 is strongly disagree and 5 is strongly agree, and 1 through 7 where 1 is strongly disagree and 7 is strongly agree. Questions where students indicated a lower than 70% rating of STEM connections are given in Figs. 3, 4, and 5.

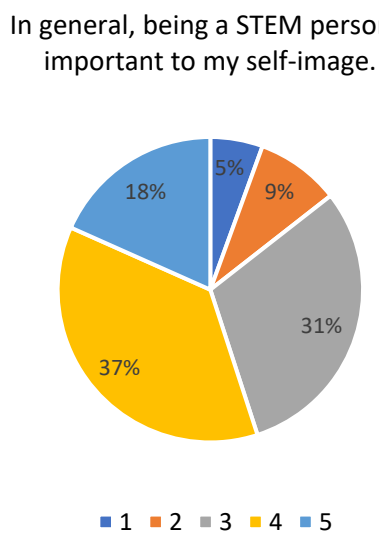

Figure 3. Student perceptions of the importance of STEM to ones self-image.

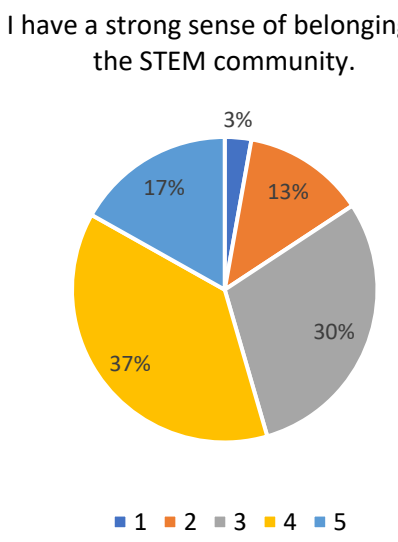

Figure 4. Student responses to having a strong sense of belonging to the STEM community.

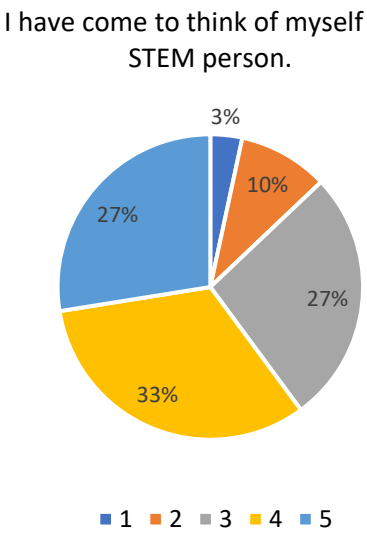

Figure 5. Perceptions about being a STEM person.

Six additional questions were asked to assess student connection to the STEM community. Similar to the individual STEM connections, half the answers indicated a 70% or greater connection to the STEM community. The other half of the answers indicated that students rated their connection with the STEM community at lower than 70%. Figures 6, 7, and 8 show the percent distribution of responses based on a ranking from 1 to 7 for how connected students felt toward their STEM community.

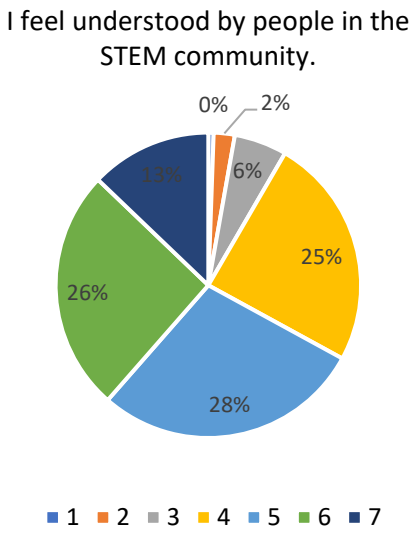

Figure 6. Feeling understood by the STEM community.

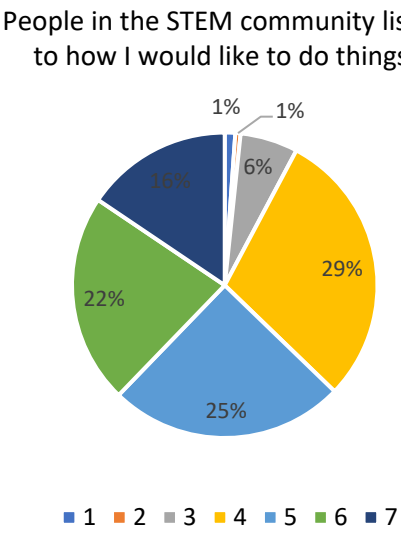

Figure 7. Feeling like one is being listened to by the STEM community.

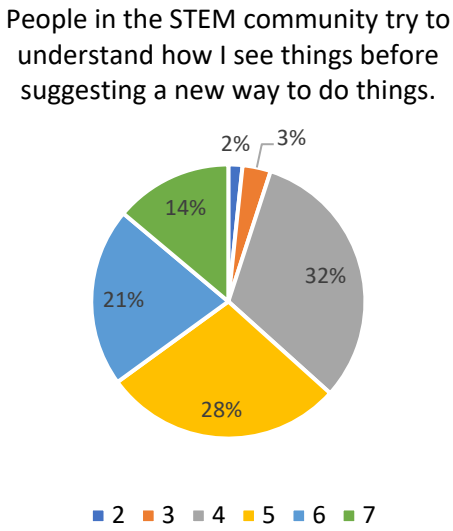

Figure 8. Being understood by the STEM community.

Student Connection to Characteristics of EM

For all the questions related to entrepreneurial mindset, over 70% of students responded that they Somewhat Agree, Agree, or Strongly Agree. The strongest agreement was with 98% of respondents indicating that other students in the course treated them with respect. Ninety-four percent and 92% of respondents indicated that they Somewhat Agree, Agree, and Strongly Agree to moving forward even when there was some uncertainty or challenges and an increased ability to generate ideas and create solutions to problems, respectively. In addition, 85% of respondents indicated that they Somewhat Agree, Agree, and Strongly Agree that the entrepreneurial skills learned in the CURE-e will help them in their major and career.

Discussion

The preliminary results indicate good success with introducing faculty to the CURE-e. Students are exposed to authentic research in lower-division STEM courses that traditionally do not provide exposure to research. Through this exposure students develop an understanding of the skills needed to perform research. A majority of students felt confident that they were learning and using STEM skills. Additional work remains to help students feel more confident in developing theories and apply research. However, these courses are designed for 1st and 2nd year students. Developing theories and applying research are higher-order cognitive skills. Even graduate students take time to refine these skills.

Students embraced a number of entrepreneurial mindset characteristics. They felt comfortable pursing challenging projects even in the face of uncertainty. Connecting the entrepreneurial mindset to ones major and career indicates that a majority of students saw the value and made the connection from school to applications beyond school. Incorporating the Entrepreneurial Mindset into a CURE was a new idea with the intention of exposing students to thinking broadly about their science discipline and to look for ways to connect the classroom learning to connections in the “real” world. Students seem to be making this connection. Introducing young STEM students to entrepreneurial skills such as brainstorming, identifying design challenges, interviewing customers, and creating customer personas are just a handful of activities available in the CEMUR CURE-e resources. Developing an EM provide practical skills students can develop without prior experience or knowledge.

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