ECURE

EXPANDING COURSE-BASED UNDERGRADUATE RESEARCH EXPERIENCES PROJECT

COMPREHENSIVE PROJECT REPORT: COHORT FOUR (2023-24)

March 31, 2025

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INTRODUCTION

Undergraduate research has been linked to increased student persistence (Gregerman, von Hippel, Jonides & Nagda, 1998; Rodenbusch, Hernandez, Simmons & Dolan, 2016; Jones, Barlow & Villarejo, 2010), improved graduation rates (Rodenbusch, Hernandez, Simmons & Dolan, 2016; Lopatto, 2004; Narayanan, 1999; Russell, Hancock & McCullough, 2007; Willis, Krueger & Kendrick, 2013), increased STEM content mastery (Willis, Krueger & Kendrick, 2013; Lopatto & Tobias, 2010), enhanced science identity (Hunter, Laursen & Seymour, 2007) and research self-efficacy (Adedokun, Bessenbacher, Parker, Kirkham & Burgess, 2013; Carpi, Ronan, Falconer & Lents, 2017). These positive effects of undergraduate research experiences are even more pronounced for students from groups typically underrepresented in STEM (URM) (Gregerman, von Hippel, Jonides & Nagda, 1998; Carpi, Ronan, Falconer & Lents, 2017; Bangera & Brownell, 2014; Chang, Sharkness, Hurtado & Newman, 2014). There is a high demand for undergraduate research experiences at the University of New Mexico (UNM), and at other colleges and universities across the country. However, interest in pursuing STEM disciplines among incoming freshman exceeds the capacity of UNM to provide early curricular or co-curricular full research experiences for undergraduates, despite evidence that such experiences boost student persistence and achievement in STEM disciplines. As a result, early undergraduate research experiences tend to serve students who come to UNM already research-ready, and minimize participation among underrepresented student populations.

To address these challenges, the University of New Mexico is implementing and testing an Expanded Course-Based Undergraduate Research Experience framework (E-CURE) that broadens early participation in undergraduate research and creates more diverse pathways to higher level research engagement. This expanded framework builds upon the traditional Course-Based Undergraduate Research (CURE) model where students engage in full research experiences by adding pre-CURE experiences where students engage in preparatory (PREP) or partial (PARTIAL) research experiences.

ECURE Project Goals and Objectives.

Goal 1. Improve lower to upper division transition rates, retention rates and STEM persistence rates for UNM STEM students through the use of undergraduate research experiences and pathways

Goal 2. Conduct research that addresses gaps in the CURE and Pre-CURE literature, and that informs instructional practices and policies at UNM

Goal 3. Develop an effective metric for measuring critical transitions from LD to UD coursework in STEM disciplines, especially for institutions where students enter with math-sequence delays

Goal 4. Increase the number of students who are introduced to research during their freshman and sophomore years, and increase the diversity of UNM undergraduate researchers by creating a more inclusive research pathway

Goal 5. Strengthen instruction in general education and portal courses through the use of undergraduate research pedagogy and experiences

Goal 6. Strengthen early science identity and science literacy for UNM STEM students, especially for those traditionally underrepresented in STEM professions

Objective 1: Train and support STEM instructors to develop, deliver and assess E-CURE-based sections of STEM general education and portal courses.

Objective 2: Train and support STEM instructors to develop approaches related to undergraduate research, science literacy, research self-efficacy and science identity.

Objective 3: Design and deliver E-CURE-based sections in multiple STEM disciplines.

Objective 4: Measure and improve lower to upper division transition rate for STEM-interested undergraduate students enrolled in E-CURE-based sections; Measure & improve retention, STEM persistence and graduation rates for STEM-interested undergraduate students enrolled in E-CURE-based sections.

Objective 5: Measure and improve science literacy, research self-efficacy and science identity for STEM-interested undergraduate students enrolled in E-CURE sections.

Objective 6: Test, refine and publish E-CURE lower to upper division transition rate metric. Through application on E-CURE redesign outcomes, test efficacy of this transition metric.

Objective 7: Study and report the comparative benefits of pre-CURE and full CURE approaches. Publish and present findings, and utilize findings to inform future instructional practices and academic policies.

ECURE PROJECT LEADERSHIP

Table 1. Project Team for Cohort Four (2023-2024)

Rosa Isela Cervantes, Director of El Centro de la Raza.
Pamela Cheek (Co-PI), Associate Provost for Student Success, and Associate Professor of French.
Hua Guo (Co-PI), Distinguished Professor of Physical Chemistry.
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Erik Erhardt (Co-PI), Associate Professor of Statistics.
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James Halloway (PI), Provost and Executive Vice President.
Aeron Haynie, Executive Director of the Center for Teaching and Learning.
Jason Moore, Assistant Professor of Paleontology, Honors College.
Tim Schroeder, Director UNM Undergraduate Research, Arts and Design Network (URAD).
Vanessa Svihla, Associate Professor of Organization, Information & Learning Sciences, with cross appointment in Chemical & Biological Engineering
Davood Tofighi, Assistant Professor of Psychology.
Assata Zerai, Vice President for Equity and Inclusion;
Lynn Nordstrom, External Evaluator.

Motivating Rationale for ECURE Implementation

UNM is motivated to build upon institutional momentum and recent pilot projects to expand early undergraduate research opportunities, improve lower to upper division transition for STEM students, enrich general education instruction, and strengthen early science identify for STEM students.

Creating New Undergraduate Research Engagements for Early STEM Students.

UNM is a Carnegie-designated Research 1 university, with world-class researchers, facilities and technology, access to three national labs, approximately $120 million in research expenditures annually and 60 NSF Career Awardees since 1995 (UNM Office of the Vice President for Research, 2018). STEM students account for 50% of all first-year students (UNM STEM Collaborative Center, 2018). These students are eager to participate in undergraduate research. In 2017 and 2018 combined, 1,155 students who registered for Freshman Orientation indicated a desire to participate in undergraduate research experiences at UNM. This high demand among early students is consistent with findings in the literature (Mahatmya et al, 2017). However, UNM has few options to offer these students for early engagement. Through curricular and co-curricular options combined, the Office of the Vice President for Research estimates that fewer than 300 freshman and sophomore students participate in research experiences. This is less than 5% of these populations, and only 30% of the known demand among freshmen and sophomores.

Reducing UNM's STEM Equity Gaps.

UNM is a university rich in diversity, with Hispanic students accounting for 49% of undergraduate enrollment, Native American students accounting for 6%, and African American students accounting for 2%. Women account for 56% of undergraduate headcount (UNM Office of Enrollment Management, 2018). Of freshmen interested in STEM degrees, 54% are Hispanic, 5% are Native American and 2% are African American. Forty-seven percent are Pell eligible (low income) and 24% are first-generation students (UNM STEM Collaborative Center, (2018). However, UNM serves one of the poorest states in the nation. New Mexico ranks third in the percentage of population living in poverty (19.1%) (U.S. Census Bureau, 2017) and ranks last in high school graduation rates (69%) (National Center for Educational Statistics, 2017). As a result, while freshman interest in UNM STEM degrees has risen over the past eight years from 39% to 51% (UNM STEM Collaborative Center, 2018), significant equity gaps exist in UNM STEM attainment.

Improving Lower Division to Upper Division Critical Transitions.

At UNM, 53% of freshmen enroll in College Algebra-level math or lower during their first semester, meaning they are still at least three semesters away from Calculus. Only 6% of entering freshmen enroll in Calculus during their first semesters (UNM STEM Collaborative Center, 2017). This means that many STEM students significantly delay their entry into upper division courses, where calculus is usually pre-requisite. During this delay, many students walk away from their STEM dreams. Thirty-six percent of STEM-interested freshmen drop out of UNM within the first two years, before transitioning to UD coursework. Another 18% switch majors out of STEM in this same period (UNM STEM Collaborative Center, 2018). The University must develop earlier research experiences for lower division students that promote successful retention and transition to upper division courses

Building Upon Pilot Efforts in STEM General Education at UNM.

In 2017, the state of New Mexico passed legislation that mandates general education courses focus on five essential skills (including critical thinking, quantitative literacy and information literacy). This legislation requires New Mexico colleges and universities to document for each general education course the methods used for weaving these focus areas into the curriculum (New Mexico Higher Education Department, 2019). The need to enrich instruction in STEM general education courses is especially compelling. Of the 20 UNM courses with the highest fail rates, 11 are STEM general education courses (UNM Office of Institutional Analytics, 2019). In Spring 2018, the UNM Provost Office established the Academic Affairs General Education Faculty Fellows Program. For this pilot project, Faculty fellows (all of whom teach general education courses) formed communities of practice to develop strategies for incorporating state-mandated general education focus areas into UNM courses. One of these faculty communities focused on Undergraduate Research. Four faculty fellows (including one from chemistry and one from paleontology) developed an *expanded* CURE framework designed specifically for the general education core, including large lecture-based sections.

This framework combines a structured pre-CURE model with the traditional full CURE model. Measuring the relative impact of pre-CURE and full CURE models is crucial to general education courses, where UNM interacts with the vast majority of our STEM undergraduate students. If the pre-CURE model is proven to be effective in producing important student outcomes relative to full CURE, then it offers significant institutional benefits when applied to the general education core. It can: 1) be implemented in large courses, including lecture sections, with minimal financial resources dedicated to teaching assistants or out-of-class research supports; 2) be used by instructors who have minimal research experience, including lecturers and teaching assistants; 3) be used in courses where students have minimal prior math or science competencies; 4) dramatically expand the number of students who can participate in the institution's research mission; 5) minimize self-selection bias in measuring the impact of undergraduate research experiences; and 6) encourage reluctant faculty members to "wade into" undergraduate research experiences, building their confidence towards full CURE implementations.

Strengthening Early Science Identity for STEM Students at UNM.

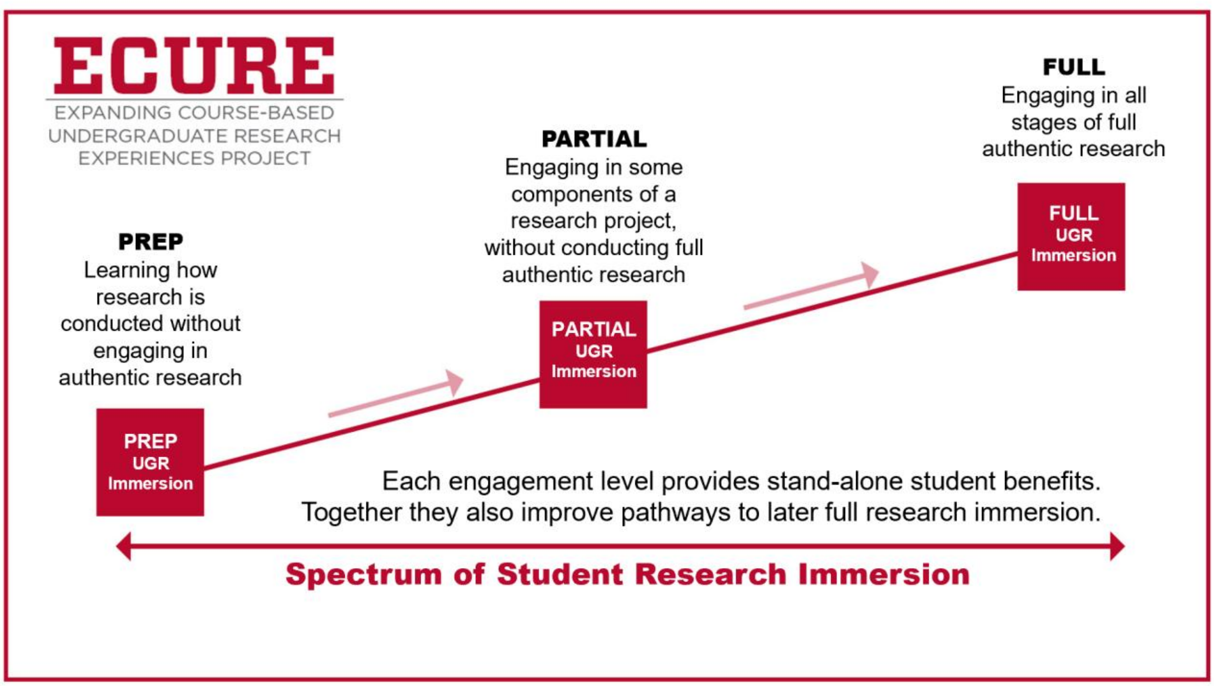
Students who feel they belong to and are a significant part of the university will invest more energy into graduating (Tinto, 1993; Pascarella & Terenzini, 1977; Terenzini & Pascarella, 1977). Teaching science literacy and helping to establish a science identity in their students is a critical task of STEM faculty. In 2014, *Revisiting the STEM Workforce: A Companion to Science and Engineering Indicators* noted that "STEM knowledge and skills enable multiple, dynamic pathways to STEM and non-STEM occupations alike" (Aschbacher & Roth, 2010), stressing the importance of providing STEM experience and enabling science literacy for all students. In addition, the manifestation of a science identity in students has been shown to influence science persistence, which is integral to the retention and graduation of STEM majors (Aschbacher & Roth, 2010; Brickhouse, Lowery & Schultz, 2000; Carlone & Johnson, 2007; Barton & Yang, 2000). Most undergraduates, even those who initially choose to pursue STEM degrees, do not readily identify themselves as being scientists (Hazari, Sadler & Sonnert, 2013). Undergraduate research experiences have been shown to encourage students to realign their individual persona and to take on more of a science identity (Robnett, Chemers & Zurbriggen, 2015; Chemers, Zurbriggen, Syed, Goza & Bearman, 2011; Egan et al, 2013). The establishment of science identity has been directly related to the generation of self-efficacy (Robnett, Chemers & Zurbriggen, 2015; Trujillo & Tanner, 2014). This realization of self-efficacy, or your belief in your ability to succeed, is intensified when your social experience emphasizes your confidence and sense of purpose (Estrada, Woodcock, Hernandez & Schults, 2011; DiBenedetto & Bernbenutty, 2013). Those undergraduates who were high in their identity as a scientist were especially likely to apply to graduate school in a science-related field (Russell, Hancock & McCullough, 2007; Robnett, Chemers & Zurbriggen, 2015) or pursue professional science careers (Hunter, Laursen & Seymour, 2007; Robnett, Chemers & Zurbriggen, 2015). By implementing an undergraduate research framework in general education and portal courses, UNM hopes to promote early science identity among the students who are most likely to leave UNM prior to graduation.

Overview of the ECURE Framework

Course-based undergraduate research experiences positively impact retention, graduation, equity, science identity, and science literacy. In comparison to out-of-class undergraduate research experiences, they provide important additional *institutional* benefits: 1) they are able to engage larger student populations who are not self-selected or pre-selected based on their perceptions of research self-efficacy; 2) they are better equipped to serve working students who cannot afford to engage outside of the classroom; and 3) they do not require the development of large co-curricular research infrastructures. However, the *student* benefits of CUREs (for instance increased science literacy and improved retention/graduation rates) are almost always connected in the literature to full and authentic research experiences, where students complete all stages of research. In STEM, these full experiences are most often implemented in lab sections, or at the upper division level.

An emerging set of literature supports the premise that "pre-CUREs" or "preparatory" research experiences (those that fall short of full or authentic research) may generate similar student outcomes, while also providing more effective pathways to research for early undergraduates. In the literature, Pre-CUREs are loosely defined, and have not been widely studied. The UNM Academic Affairs General Education Faculty Fellows further characterized and defined the pre-CURE model to create an expanded CURE framework designed specifically for general education courses. This expanded framework categorizes pre-CURE into two levels of student immersion in research: preparatory instruction (PREP), and partial research engagement (PARTIAL). When combined with the traditional full CURE model, this framework can be implemented more extensively through the general education core, including in large lecture sections.

Figure 1. ECURE Framework



Course-based Undergraduate Research Experiences (CURE). E-CURE builds upon the foundation of the CURE model. CUREs are defined as "learning experiences where whole classes of students address a research question or problem with unknown outcomes or solutions that are of interest to external stakeholders" (Dolan, 2016). CUREs have been primarily developed for biology and chemistry lab courses (Dolan, 2016), but CUREs have also been implemented in engineering (Moore & Diefes-Dux, 2004; Reeves & Laffey, 1999), geosciences (Ryan, 2014), and physics (Beckham, Simmons, Stovall & Farre, 2016), among many other disciplines. CUREs have been linked to increased content mastery and improved scientific literacy, as well as to increased retention, degree persistence and graduation rates (Rodenbusch, Hernandez, Simmons & Dolan, 2016; Dolan, 2016; Brownell et al, 2015). CUREs and other undergraduate research experiences are considered to be especially useful for women and underrepresented minority students (Gregerman, Lerner, von Hippel, Jonides & Nagda, 1998; Carpi, Ronan, Falconer & Lents, 2017; Bangera & Brownell, 2014; Chang, Sharkness, Hurtado & Newman, 2014). CUREs are backed by an extensive literature, national alliances, reports, professional associations and instructional/administrative resource websites.

CUREs are most often *defined* through the use of essential elements that all must be present for the course to be considered a CURE (see Table 2). In addition to these essential elements, CUREs are sometimes *described* by the instructional mechanisms, activities and/or research practices used in implementation. Examples include "asking questions, building and evaluating models, proposing hypotheses, designing studies, selecting methods, using the tools of science, gathering and analyzing data, identifying meaningful variation, navigating the messiness of real-world data, developing and critiquing interpretations and arguments and communicating findings (Auchincloss et al, 2014)." An example of a CURE might include a class project where students collectively identify a real-world problem, conduct a preliminary literature review, design a research study, collect data, analyze data, and publish or present their findings. CUREs are most commonly utilized in labs courses, upper division courses, and courses with low enrollments.

Table 2. Traditional Full CURE Essential Elements (Auchincloss et al, 2014)

Scientific practices	**Uses generally accepted scientific practices to answer research questions**
Discovery	Generates new knowledge, insights or understanding (focuses on questions where the answers are unknown).
Broadly relevant or important work	Findings are meaningful and important beyond the classroom
Collaboration	Involves teams of researchers working together
Iteration	Builds upon previous research and current knowledge

Pre-CURE. E-CURE expands upon emerging pre-CURE approaches. While the CURE framework has been widely defined and described in the literature, an emerging body of research describes the importance of course-based research experiences that do not meet the standards or definition of traditional CUREs. These experiences are sometimes called Pre-CUREs or undergraduate research pathways. Pre-CUREs are defined as learning about research outside of a full research setting.

In the literature, pre-CUREs are sometimes described as "modular" implementations (Horsch, St. John & Christensen, 2012). Pre-CUREs teach students concepts such as iteration, thinking critically about research, and learning about research methods and experimental design (Mahatmya et al, 2017). These courses provide more tangible connections between lectures and lab or real world applications (Horsch, St. John & Christensen, 2012), contribute to the development of student confidence, and encourage students to participate in research experiences (Mahatmya et al, 2017). Preparatory research experiences also improve pathways to undergraduate research for traditionally underrepresented students (Hurtado, Cabrera, Lin, Arellano & Espinosa, 2009). This is especially true for students who cite lack of research preparedness as the primary barrier to their participation

(Mahatmya et al, 2017). Though pre-CUREs are gaining in popularity, and have been linked to improved retention rates (Horsch, St. John & Christensen, 2012), there have been few large multi-disciplinary implementations of pre-CUREs designed to compare outcomes to traditional CUREs.

Structure of the ECURE Project

Building upon an expanded CURE framework developed by UNM's Academic Affairs General Education Faculty Fellows, E-CURE: 1) collects and analyzes course-level data to identify which STEM general education and portal courses could most benefit from pre-CURE and/or full CURE implementations, 2) works with academic administrators to select courses and instructors to incorporate pre-CURE and full CURE into their sections, 3) trains instructors to effectively incorporate pre-CURE and full CURE, 4) assess the relative impacts of pre-CURE and full CURE implementations on student perceptions and behaviors, 5) distributes findings through publications and presentations, and 6) institutionalize pre-CURE and full CURE inclusion in UNM general education and portal courses.

Operationalizing the E-CURE Framework.

The UNM Academic Affairs General Education Faculty Fellows characterized and defined the *pre-CURE* approach to create an *expanded* CURE framework designed specifically for general education courses. This structured pre-CURE framework categorizes two entry levels of student immersion in research as preparatory instruction (PREP) and partial research engagement (PARTIAL) This structure is similar to the engagements described by Gentile, Brenner and Stephens, who note that "students can realize the benefits of research at any stage" (Gentile, Brenner & Stephens, 2017). It is anticipated that PREP pre-CURE will produce different student outcomes than PARTIAL pre-CURE, and that both forms of pre-CURE will produce different student outcomes than full-CURE. Our research design will identify & measure the differences in student outcomes for each approach.

In the E-CURE Framework, PREP is defined as teaching students how research is conducted (including explaining the connection of foundational skills to research processes), but *without* actual engagement in research. PREP can be taught in either lecture or active learning environments. In the traditional CURE literature, PREP is specifically and intentionally excluded from the CURE definition/model (Gentile, Brenner & Stephens, 2017; Auchincloss et al, 2014).

<u>E-CURE operationalizes the PREP definition as providing at least ten separate activities, assignments or focused lectures addressing research skills or research-applied foundational skills during the course of an academic term</u>. Examples include teaching students to differentiate between correlation and causation, exploring the value of peer-based literature compared to Wikipedia, or using MS Excel to determine significance.

In the E-CURE framework, PARTIAL is defined as engaging students in selected components of research, *without* engaging in all of the essential elements of full CUREs. In the literature, PARTIAL is generally excluded from the CURE definition/framework because it does not include all of the essential elements. An example of PARTIAL might an include a class where students are provided a research problem by the instructor (rather than identifying one themselves), are provided a summary of existing knowledge (rather than conducting their own lit reviews), are provided with a research method (rather than selecting their own), are required to collect & analyze data individually, and report their findings to the instructor in a research journal (rather than sharing with research peers). <u>E-CURE operationalizes the PARTIAL definition as engaging students in at least one of the essential CURE element, within a context in which students ask or answer questions to which the answers are unknown</u>. This definition differentiates PARTIAL experiences from cookbook experiments. In order to compare the impact of pre-CUREs to full CUREs<u>, E-CURE also operationalizes the definition of a full CURE as engaging students in a research project that involves all five essential CURE elements</u>.

Course Analysis, Fellows & Project Recruitment and Selection.

E-CURE follows a process for identifying course redesign projects developed by the UNM STEM Gateway Project (funded by US Department of Education Title V STEM Grant, concluded 2017). This process is both bottom-up and top-down, in order to encourage participation and sustainability. The ECURE Project Director convenes an

Administrative Workgroup, composed of faculty within the Center for Teaching and Learning, Deans or Associate Deans in Arts & Sciences, Engineering, and Honors, and Department Chairs or Associate Chairs in six STEM disciplines (with preference placed on participation by math, biology, chemistry and physics Chairs). This workgroup reviews course success data prepared by UNM institutional researchers in order to identify courses most in need of redesigned sections. Workgroup members then recruit instructors to apply for E-CURE Redesign Faculty Fellowships.

Types of ECURE Teaching Fellowships.

ECURE supports Implementation Fellows and Exploratory Fellows. Implementation Fellows develop and implement ONE of the three levels of immersion in at least one section of a STEM general education or portal course. Each Implementation Fellow receives a $4,000 summer stipend. Exploratory Fellows explore the use of the ECURE framework in their courses by observing their peers implement projects, but will not commit to an implementation themselves. Exploratory Fellows are encouraged to apply as Implementation Fellows next year, if they feel this is an appropriate framework for their course(s). Exploratory Fellows receive a $1,000 summer stipend. Former Implementation Fellows are also encouraged to apply as Publication Fellows. Publication Fellows will be supported in submitting their course project and findings for publication.

Fellows Recruitment.

ECURE staff worked with the UNM Provost Office to develop a Request for Participation process in combination with the UNM Student Experience Project (funded by the APLU). This process encouraged faculty to learn about both programs, and to select which of the two best fit their instructional needs. Due to Covid delays, this RFP went out in early May, with a June 5 deadline. We were able to accept/fund 100% of applicants who met our participation requirements.

ECURE Websites.

ECURE staff created a project website to describe the project, request faculty participants, and link participants to key resources. This site is located at: https://urad.unm.edu/faculty-staff/ecure.html

ECURE staff partnered with UNM Libraries faculty to create a new UNM Undergraduate Research Resource Guide, which lists journals, articles and other resources to support faculty in building ECURE implementations. This site is located at: https://libguides.unm.edu/UGR-resources

Faculty Development, ECURE Summer Institute

Cohort Three ECURE Summer Institute Report and Communities of Practice

ECURE Summer Institute: The 2023 ECURE Summer Institute (ECSI) built on the great work of participants from the previous years. ECSI is offered virtually through the UNM course management system, with four synchronous sessions (three hours each), and the remainder of the institute offered asynchronously through discussion boards and other online tools. This allows ECSI to meet busy and varied faculty summer schedules. Based on responses from Year One and Year Two, we expanded the summer institute from four weeks to eight weeks, which encompassed the majority of the summer. Since ECURE contains elements of both professional development and course redesign work, four weeks did not quite provide instructors enough time to learn, reflect, incorporate, reflect and revise. Consequently, we switched to eight weeks. However, this revised schedule did not change the number of or duration of synchronous sessions.

As with previous years, ECSI for Cohort Four focused on professional development around the following four primary areas: Course-Based Undergraduate Research (CURE), Culturally Responsive Pedagogy (CRP), effective online instruction (in response to the COVID pandemic); and Active Learning Strategies (ALS). Engagement during ECSI is strategically designed to foster peer-to-peer and fellow-to-instructor dialogue and includes minimal instructor-to-fellow lectures/presentations.

Institute Goals: The ECURE Summer Institute provided professional development for 24 general education and portal course instructors. Learning goals and objectives included:

GOAL 1: Participants will understand and appreciate the differences between directing and carrying out research practices. Upon completion of the institute, participants will be able to:

- Describe high and low agency research practices salient to courses taught
- Identify barriers to students directing research practices
- Plan strategies to surmount these barriers
- Connect research-based outcomes for students who carry out versus direct research practices in terms of content mastery, research efficacy, science literacy, and science identity

GOAL 2: Participants will understand and appreciate asset-based and culturally-responsive teaching (CRT). Upon completion of the institute, participants will be able to:

- Describe specific strategies to build rapport with and show care for students
- Describe ways to identify research skills diverse students bring from their cultural and everyday lives and position them as researchers
- Adapt research-based, CRT strategies for use in their course
- Explain the outcomes of CRT for all students in terms of content mastery, research efficacy, science literacy, and science identity

GOAL 3: Participants will understand and appreciate active learning strategies. Upon completion of the institute, participants will be able to:

- Adapt research-based, active learning strategies for use in their course

GOAL 4: Participants will value faculty learning community. Upon completion of the institute, participants will be able to:

- Explain benefits of participation in a faculty learning community
- Describe strategies for making effective use of a faculty learning community

Facilitators: The Summer Institute was facilitated by the following UNM administrator and faculty:

- Dr. Tim Schroeder, Director, UNM ECURE Program; Director, UNM URAD.
- Dr. Cristyn Elder, Associate Professor and Director, Rhetoric and Composition, Department of English; Director of Writing Across the Curriculum, Center for Teaching and Learning; ECURE Summer Institute Curriculum Development
- Dr. Vanessa Svihla, Associate Professor, Organization, Information & Learning Sciences, with cross appointment in Chemical & Biological Engineering; E-CURE Educational Researcher; ECURE Summer Institute Curriculum Development
- Dr. Jason Moore, Associate Professor, Honors College.

ECURE Impact Assessment

Pre and Post Surveys.

During the Spring and Summer of 2020, ECURE researchers met to review established assessment tools, including the Test of Scientific Literacy Skills, the SURE and CURE surveys, the Colorado Learning Attitudes about Science Survey, the Experimental Design Ability Test, and the Project Ownership Survey. While none of these instruments perfectly fit our needs, most contributed important elements to our assessment goals.

After a careful review of existing CURE surveys, we decided to develop a new pre/post survey that could fit our context well and that followed best practices in survey design (Dillman et al., 2016; McCoach et al., 2013). More specifically, we defined constructs of interest (research identity, cultural compatibility, research self-efficacy, and intent to persist in research). Many of these constructs had well-developed surveys (Davidson et al., 2009; Echohawk et al., 2014; Estrada-Hollenbeck et al., 2011; Hanauer et al., 2016; Robnett et al., 2015; Trujillo & Tanner, 2014), but typically in a specific domain like science or engineering. We adapted these for the broader context of research processes.

Table 3. Questions by construct. Items included constructed response questions to promote specificity and Likert 7-point scaled items.

Research identity	How important or unimportant is being a researcher to your self image? How strong or weak is your sense of belonging to a community of researchers? How much or little do you perceive yourself as a researcher right now? How much or little do you perceive yourself as a future researcher?
Cultural compatibility	How compatible or incompatible is doing research with your cultural values? How compatible or incompatible is a career in research with your cultural values?
Research self-efficacy	How unconfident or confident are you that you can: o use technical skills (use of tools, instruments, and/or techniques of your field of study) to do research? o generate a research question to answer? o figure out which data/observations to collect and how to collect them? o explain the analysis results? o use academic literature to guide your research?
Intent to persist	How certain or uncertain are you that you will earn a degree in your current or intended major? How strong or weak is your intention to persist in: o your pursuit of your current or intended degree? o courses that include research experiences? o a research experience, such as a summer program or working in a faculty or national lab?

Research Literacy Curricular Assessment Tool.

The ECURE Research Literacy Performance-based Assessment (RLPA) was developed to assess changes in students' ability to design and assess primary STEM research, and to extract and communicate the results of such research to a non-specialist audience. The RLPA was developed for ECURE by Drs. Vanessa Svihla, Cristyn Elder, and Jason Moore. A number of existing instruments that could be used for assessing similar skills were examined during the development of the RLPA (TOSLS, Gormally et al. 2017; EDAT, Sirum and Humberg 2011; AAC&U VALUE, Rhodes 2010), but all were found to be either too disciplinarily specific or to have insufficient research focus for this project. Hence the RLPA was developed *de novo*.

One of the major challenges in designing this approach was that the instrument needed to be sufficiently specific to be applied within a particular disciplinary course and to be scored by instructors with that disciplinary knowledge, but sufficiently general to allow for valid comparison across the range of disciplines included in the study. It was also determined that the instrument had to be completed within 30 minutes to minimize in class disruption.

The RLPA was designed with two questions, each of which was crafted into a template to be modified to account for the disciplinary focus of each class participating in ECURE. Participants were given instruction and examples as to how to modify each question's template to fit their discipline. Both questions were designed to assess skills that are common to research across STEM disciplines (e.g. project design), rather than disciplinary skills (e.g. statistical analysis).

Question 1: Imagine you are working on a research project and you are writing instructions that your classmate will carry out. The purpose of the research is to [purpose here]. More specifically, the project investigates [hypothesis or research question here. Add a brief description as needed]. Explain how you would investigate this question. Be as specific as you can be about the sequence of steps you would take. Provide detail (how, when, where, what, and who) such that your classmate could follow your instructions.

This question was designed to assess a student's ability to develop a research plan to address a question they had been posed and communicate that plan. We designed a rubric to partner with this question to assess students' ability to design a comprehensive research plan that was sufficiently detailed and proceeded logically, and communicate that plan at an appropriate level.

Question 2: Your partner on a research project drafts results for a poster you will both present at a regional conference. They share a draft with a research question, figure and bullet points below, which relate to data you collected and analyzed. [provide a brief description of the study, and the information from the poster that should be improved, including a weak or flawed research question, poorly represented/selected data, and bullets that don't match the data].

1. *Write a three- or four-sentence summary of the research project that communicates the main findings to an interested friend or family member who isn't familiar with the project.*

2. *In addition, write constructive criticism of the draft for your partner. Be specific about what changes or additions you would make to overcome any problems you notice, and why you would make those changes/additions. Make sure to provide feedback about the (1) research question, (2) figure, and (3) bullet points.*

This question was designed to assess a student's ability to critique a complete research study that they had been presented and to synthesize and communicate the significance of this study to another audience. As with Question 1, a rubric addressing each of these research-related skills was developed to accompany this question.

The rubrics are scored on a 3-tier scale (-1, 0, 1) to maximize inter-instructor congruence in scoring while still capturing shifts at the class level. Complete scoring of both questions assess students' skill at:

- Development of a comprehensive approach to a research question
- Development of an appropriately detailed approach to a research question
- Development of a logically ordered approach to a research question
- Appropriate communication of research ideas (x2)
- Identification of research questions from provided data
- Synthesis of existing research
- Critical analysis of existing research

Several of the examples for each question were trialed informally to ensure that they were unambiguously comprehensible to students of similar background to those who would participate in the study.

CREATION OF PROCESS TO ESTABLISH BASELINE STUDENT POPULATION.

To develop stronger measures of assessing ECURE impact on student outcomes, UNM researchers developed a method for identifying a comparison student population who did not receive ECURE interventions. In course-based undergraduate research initiatives, baseline populations are often pulled from non-intervention sections of the same course. This option was not available to us, as some of our ECURE courses are only offered in one section per semester, without non-intervention sections to draw from. To solve this challenge, we first developed a list of key student variables (i.e., gender, ethnicity, class standing, college/school, SES). Second, we pulled the course rosters for each of the ECURE sections, and then pulled the data for those key variables for each student. After de-identifying the students, we then utilized statistical matching to identify three UNM students not enrolled in any ECURE section matched to each ECURE-enrolled student. We then surveyed the baseline population using the same survey tool as ECURE students.

This baseline population is also utilized for measuring impact on non-survey outcomes, including college retention, degree persistence, and graduation.

Matching Description and Rationale: In the UNM ECURE trial, we evaluate the educational effects (science literacy, science identity, research self-efficacy, and likelihood to persist) of the levels of the ECURE Framework (Prep, Partial, or Full) by prospectively comparing students with undergraduate research experiences (treatment) to those with "standard" experiences (non-treated, "control"). In our prospective cluster randomized controlled trial, classes of students (clusters) either undergo an ECURE treatment or not, where the treated classes are self-selected by the instructors. While one of the disadvantages of this design compared with an individually randomized controlled trial is that the experiences of individuals within the same group are likely similar, leading to correlated results (Campbell, Melbourne, Altman, 2004), the design is being strengthened by a priori bipartite matching. We perform case-control matching to find, for every treated student, at least one non-treated student with similar ("balanced") observable characteristics against whom the effect of the treatment can be assessed (Rubin, 1973). By matching treated units to similar non-treated units, matching enables a comparison of outcomes among treated and non-treated units to estimate the effect of the treatment reducing selection bias due to confounding (Rubin, 1973; Anderson, Kish, Cornell, 1980; Kupper, et al., 1981).

Increasing the number of controls above the number of cases, up to a ratio of about 4-to-1, is a cost-effective way to improve the study (Grimes and Schulz, 2005); furthermore, the 4-to-1 matching accounts for attrition (lack of participation) from students in the control group. Matching techniques have improved over propensity scores, which has been shown to increase model dependence, bias, inefficiency, and power and is no longer recommended compared to other matching methods (Rosenbaum and Rubin, 1983; King and Nielsen, 2019). We use a multivariate matching technique with automated balance optimization with the "Matching" R Package (Jasjeet, 2011). We use the "GenMatch" function to find the optimal balance using multivariate matching where a genetic search algorithm determines the weight each covariate is given.

As a quality check, we also implement standard methods implemented in the "Match" function and compare the covariate balance before and after matching (using the MatchBalance function). This matching strategy does not make the same strong assumptions that propensity scores and Mahalanobis distance make that covariates have ellipsoidal distributions, but instead searches over a space of distance metrics and finds a better metric. The "GenMatch" function has been shown to have better properties than the usual alternative matching methods both when the ellipsoidal distribution property holds and when it does not (Sekhon 2006a; Diamond and Sekhon 2005). We implemented the GenMatch function genetic algorithm with 4 matches, a population size of 1000, the "pvals" fit function, no ties, with several covariates: current age, gender, ethnicity, college (A&S, Engineering, etc.), academic level (1-4 for freshman-senior), number of transfer credits (coming from another school), number of 100-400 level credits enrolled in at UNM for Fall 2021, number of Fall 2021 STEM General Education credits, Pell Grant receiving status (SES indicator), and number of STEM General Education currently enrolled in at UNM for Fall 2020. Categorical variables were coded using a design matrix with a specified baseline and indicator variables indicating when not the baseline category.

COHORT FOUR PRELIMINARY FINDINGS

TABLE 4. PARTICIPATION NUMBERS, COHORT FOUR.

ECURE faculty fellows	**28**
ECURE sections offered	**138**
Undergraduates enrolled in E-CURE section	**2263**

LIST OF ECURE COURSE IMPLEMENTATIONS, COHORT TWO.

- **BIOC 495 Topics in Biochemistry**
- **BIOL 1110L, General Biology Lab**
- **BIOL 2305, Microbiology for Health Sciences**
- **BIOL 302C Genes to Genomes: Lecture and Laboratory**
- **BIOL 406 Topics in Organismal Biology**
- **CHEM 1215L, General Chemistry I for STEM Majors Laboratory**
- **CHEM 1225L, General Chemistry II for STEM Majors Laboratory**
- **ECE 203 Circuit Analysis I**
- **ECON 2120, Microeconomic Principles**
- **ENVS 320 Environmental Systems**
- **ENVS 322L, Life & the Earth System**
- **GEOG 1115, Maps & GIS Science**
- **GEOG 2115, Information Design in Science and Society**
- **LING 2151, Language of Advertising**
- **POLS 2110, Comparative Politics**
- **POLS 2140 Introduction to Political Analysis**
- **SOC 398 Special Topics in Sociology**

COHORT THREE IMPACT NARRATIVE

Limitations: There is one important limitation to the preliminary findings from Cohort Four: This dataset encompasses 25% of our projected data. Cohorts One through Four combined contain the student enrollments that will complete our study. During the no-cost extension year of ECURE, the data from all four cohorts will be combined, and a comprehensive analysis will be conducted on our multi-year cross-disciplinary project. This approach will allow us to overcome and better understand the influence of the Covid lockdown and will help us to better measure impact based on important varying considerations (for instance, the student impact of an instructor's first implementation compared to their fourth implementation). In addition, this will allow us to determine whether impacts that are observed in one cohort, but not in the next, are in fact meaningful in the long-term, or are unrelated to ECURE interventions.

Analysis Structure and Definitions: Cohort Four Data comes from two sources: pre and post ECURE surveys; and student records in Banner. Cohort Three student populations are primarily: students in ECURE courses/sections (ECURE or TREATMENT); and students not-in ECURE courses/sections who have been matched to ECURE students using demographic and academic variables (CONTROL). Matching variables include race, ethnicity, gender, age, Pell-receiving status, academic standing, and STEM-affiliation, among others.

ECURE students are further subdivided into three categories: students in ECURE courses/sections with "full" research engagement level 21 (FULL); students in ECURE courses/sections with "partial" research engagement (PARTIAL); and students in ECURE courses/sections with "preparatory" research engagement (PREP).

Survey-based data were analyzed using two approaches. First, we compared changes in student responses on the pre and post surveys (GAINS). While this approach provides the most accurate assessment of gains or losses throughout the ECURE semester, it also comes with one primarily limitation. Since response rates for CONTROL students have been lower than desired, the number of these students who have completed both the pre and the post surveys reduces our confidence level in these findings. As a result, we also utilized an "end of term" approach (EOT). EOT allows us to compare end-of-semester perceptions, based only on student responses on the post surveys

Analysis methodology: To evaluate differences associated with either Treatment or ECURE engagement level, we used multiple linear regression for selected survey questions (Likert-scale treated as numeric) and multiple logistic regression for STEM/non-STEM major persistence, college retention, and upper-level transition success. Multiple linear regression adjusted for Gender, Ethnicity and Race, Pell Status, and Academic Standing, and stepwise model selection with Akaike Information Criterion (AIC) was used to identify the explanatory factors; the stepwise starting model is the main-effects model with the scope up to the full two-way interaction model and the minimum model of only with Treatment or ECURE engagement level. Multiple linear regression model fit assumptions on the residuals are equal variance and normality, which are both assessed visually. Multiple logistic regression assesses model fit using a deviance lack-of-fit test. All models satisfied model assumptions prior to interpretation.

COHORT FOUR PRELIMINARY FINDINGS: Cohort Four included 28 instructors teaching 138 sections of STEM courses in the Fall of 2023 and the Spring of 2025 combined. Cohort One was implemented during the first semesters of Covid lockdown, with most courses offered online. Cohort Two was implemented during a time when the University was rebounding from the lockdown, with some courses offered online and some offered face to face. Cohort Three was implemented during a time when most courses had returned to face to face. Cohort Four was implemented when courses had completely returned normal operations.

The analysis methods from Cohort Four were the same as from Cohorts One, Two, and Three, yet produced different preliminary findings.

During Cohort One, we observed some statistically significant differences in the outcomes between students enrolled in ECURE courses [ECURE] and students in the control group who were not enrolled in ECURE courses [CONTROL]. Also, in Cohort One, we observed few statistically significant differences in the outcomes between the three ECURE engagement levels (preparatory [PREP], partial [PARTIAL] or full [FULL]).

During Cohort Two, we observed two important trends. First, in several key variables, we noted that student outcomes increased steadily across the ECURE engagement spectrum. For these variables, the outcomes were lowest for students in the CONTROL population, slightly higher for students engaged in PREP ECURE sections, higher again for students engaged in PARTIAL ECURE sections, and highest for students engaged in FULL ECURE sections. Second, we saw that ECURE benefits do not appear to be consistently applied across student categories. Rather, ECURE appears to benefit women and minoritized student populations more than it does men and privileged student populations (though on rare occasions, that trend is reversed). Both of these trends are promising, and support our rationale from the original ECURE proposal to the National Science Foundation.

During Cohort Three, we did not see evidence that student outcomes increased steadily across the ECURE engagement spectrum, as occurred during Cohort Two. Rather, the results from Cohort Three are more similar in this respect to Cohort One. However, we did notice an important similarity between Cohorts Two and Three: ECURE appears to benefit females student populations more than it does male student populations. In other words, ECURE instruction appears to help level the playing field for women. And in Cohort Three, this impact occurs regardless of the ECURE engagement level (PREP, PARTIAL or FULL).

Again, during Cohort Four, we noticed no distinctions between the three engagement levels, but we did observe that the ECURE intervention shows significant but sometimes conflicting impacts relative to STEM degree enrollment and gender.

Preliminary findings from Cohort Four include the following:

Impact on science literacy

Science Literacy was assessed based on a seven-point scale (ranging from "very unconfident" to "very confident") on the following five questions (from Question 19 on the pre and post surveys):

How unconfident or confident are you that you can...
(Sub-Question 1 [SQ1]) use technical skills (use of tools, instruments, and/or techniques of your field of study) to do research?
(SQ 2) generate a research question to answer?
(SQ 3) figure out which data/observations to collect and how to collect them?
(SQ 4) explain the analysis results?
(SQ 5) use academic literature to guide your research?

Summary: In Cohort Four, we observed that students in ECURE sections showed significant GAINS in general science confidence levels compared to their non-ECURE peers, especially in subpopulations related to STEM/non-STEM degree enrollment and gender. This is similar to our findings in Cohort One and Three, but not Cohort Two. We did not see that these gains were differentiated by ECURE engagement level (PREP, PARTIAL or FULL). Again, this is similar to Cohort One and Three, but not Cohort Two. We observed an interesting "leveling the splaying field" effect for women and non-STEM majors. This effect is similar to ones observed in Cohort Two and Three. We observed no significant associations with the ECURE treatment (as a whole, or differentiated by engagement levels) for race/ethnicity).

Specific Findings: GAINS in ratings from the pre-survey to post-survey reveal the following significant associations:

(SQ 1, technical skills) TREATMENT female students showed 1.85 higher confidence GAINS than CONTROL female students.

(SQ 2, generating research question) CONTROL STEM students showed 2.94 higher confidence GAINS than CONTROL non-STEM students. In the TREATMENT population, there is no difference in confidence GAINS between STEM and non-STEM students. In the TREATMENT population, the ECURE intervention appears to level the playing field for STEM and non-STEM students regarding confidence in generating research questions.

(SQ 3, data and observations) CONTROL STEM students showed 2.69 higher confidence GAINS than CONTROL non-STEM students. In the TREATMENT population, there is no difference in confidence GAINS between STEM and non-STEM students. In the TREATMENT population, the ECURE intervention appears to level the playing field for STEM and non-STEM students regarding confidence in data and observation skills. For both STEM and non-STEM TREATMENT students, confidence gains were both slightly higher than for CONTROL STEM students.

(SQ 4, explaining results) CONTROL STEM students showed 3.38 higher confidence GAINS than CONTROL non-STEM students. In the TREATMENT population, there is no difference in confidence GAINS between STEM and non-STEM students. In the TREATMENT population, the ECURE intervention appears to level the playing field for STEM and non-STEM students regarding analysis explanation skills. Both STEM and non-STEM TREATMENT students showed confidence gains roughly equal to CONTROL STEM students.

(SQ 4, explaining results) TREATMENT male students showed no confidence GAIN differences compared to CONTROL populations. However, TREATMENT female students showed 2.94 higher confidence GAINS than CONTROL female students. Male and female TREATMENT students showed slightly higher confidence GAINS than CONTROL male students. ECURE interventions appear to level the playing field between male and female students regarding confidence in explaining results

(SQ 5, academic literature) CONTROL STEM students showed 2.51 higher confidence GAINS than CONTROL non-STEM students. In the TREATMENT population, there is no difference in confidence GAINS between STEM and non-STEM students. In the TREATMENT population, the ECURE intervention appears to level the playing field for STEM and non-STEM students regarding confidence in utilizing academic literature. For both STEM and non-STEM TREATMENT students, confidence gains were both slightly higher than for CONTROL STEM students.

Specific Findings: EOT (End of Term) ratings from the post-survey reveal the following significant associations:

(SQ 1, technical skills) CONTROL STEM students show the same EOT confidence levels as CONTROL non-STEM students. TREATMENT STEM students show EOT confidence levels 0.44 higher than TREATMENT non-STEM. TREATMENT and CONTROL non-STEM students show no difference in EOT confidence levels. TREATMENT STEM students show the highest EOT confidence levels of any subpopulation.

(SQ 1, technical skills) TREATMENT females show the same EOT confidence level as CONTROL females, but TREATMENT males show 0.376 higher than CONTROL males.

(S SQ 2, generating research question) TREATMENT male students show EOT confidence levels 0.491 higher than CONTROL male students. Female students do not differ in EOT confidence levels between CONTROL and TREATMENT.

<u>Impact on research self-efficacy</u>

Research efficacy was assessed based on *four* questions from the pre and post surveys.

(Q14) “As of today, how important or unimportant is being a researcher to your self image?”
(Q15) "How strongly or weakly is your sense of belonging to a community of researchers?"
(Q16) "How much or little do you perceive yourself as a researcher right now?"
(Q17) "How much or little do you perceive yourself as a future researcher?"

Summary: Specific Findings: In Cohort Four, we observed fewer associations in relation to research efficacy and identity than in Cohort Two, but similar to Cohort One and Three. We observed a significant association based on gender, but not on race/ethnicity. We also observed that the ECURE treatment appears to close the gap in confidence levels between STEM and non-STEM students, and this has been consistently observed across all cohorts.

Specific Findings: Question 15, GAINS:

In the CONTROL population, STEM students showed gains 2.23 higher than non-STEM students. But in the TREATMENT population, STEM and non-STEM students showed no difference.

TREATMENT male students show 1.43 higher GAINS than CONTROL male students. TREATMENT female students show no difference in GAINS compared to CONTROL female students.

Specific Findings: Question 16, GAINS:

In the CONTROL population, STEM students showed GAINS 1.680 higher than non-STEM students. But in the TREATMENT population, STEM and non-STEM students showed no difference. TREATMENT non-STEM students showed GAINS 2.13 higher than CONTROL non-STEM students.

Specific Findings, Question 14, End of Term (EOT):

In the TREATMENT population, STEM students showed EOT confidence levels 0.635 higher than non-STEM students. In the CONTROL population, STEM and non-STEM students show no difference in EOT confidence levels.

Impact on increased next-semester retention

Summary: In Cohort One, we observed an increased likelihood of next-semester retention for the ECURE students compared to the CONTROL students. However, in Cohort Two, no such associations were observed. In Cohort Three, we observed a quite dramatic increase in next-semester retention for ECURE students compared to their non-ECURE peers. In Cohort Four, we observed no such overall increases, but we observed somewhat conflicting results showing an increase in retention for non-STEM students, but a decrease for STEM students.

Specific Findings:

For non-STEM students, next-semester retention is 66% lower (RR=091) for CONTROL students (.0882) than for TREATMENT students (0.988). For STEM students, next-semester retention is 67% higher (RR=1.67) for CONTROL (0.957) than for TREATMENT students (0.931).

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