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An Investigation into Student Development from STEM Undergraduate Research
Experiences Through a Focus on Teaching and Mentoring Practices

by
Anthony O Garcia

A dissertation submitted in partial satisfaction of the
requirements for the degree of
Doctor of Philosophy
in
Chemistry
in the
Graduate Division
of the
University of California, Berkeley

Committee in charge:

Professor Anne M. Baranger, Chair

Professor Matt B. Francis

Professor Robert J. Full

Spring 2026

An Investigation into Student Development from STEM Undergraduate Research
Experiences Through a Focus on Teaching and Mentoring Practices

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By

Anthony O Garcia

Abstract

An Investigation into Student Development from STEM Undergraduate Research

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University of California, Berkeley

Professor Anne M. Baranger, Chair

My dissertation features an overview of 3 studies relating to the Berkeley Undergraduate Research Evaluations Tools (BURET) project. The BURET project was initiated to develop qualitative and quantitative research tools and protocols to evaluate how learning and mentorship are being experienced by undergraduate students who are involved in faculty laboratory research. The BURET project was also tasked with answering the following three questions: 1) What do undergraduate researchers learn about scientific content and research practices? 2) What practices do graduate students and post-docs report using when teaching and mentoring undergraduate researchers? 3) What teaching and mentoring practices do undergraduates report in their research experiences? I have carried out three studies that together focus on research impacts in the K-12 classroom, measurement of student mentoring and teaching in undergraduate research experiences (UREs), and analysis of interventions carried out towards mentorship training and coaching of chemistry graduate students. My research studies expand upon the original scope of the BURET project. At a broader level, my goal is to provide insight into the experience of learning and engaging in chemistry and the impacts of said engagement at later career stages for students.

The first study I have worked on for the BURET project was a collaboration with the CalTeach program at my institution where I investigated which teaching practices used by K-12 STEM teachers were influenced by the undergraduate research experiences they participated in as pre-service teachers in the CalTeach program and in what ways undergraduate research experiences have affected the instruction or attitudes towards teaching in STEM. Data collected were interview transcripts from the teachers about how research influences their teaching, and analysis was carried out through descriptive assessments and coding. We developed our own coding scheme based on several educational frameworks and the Next Generation Science Standards. From our coding analysis, we obtained findings that indicate that teachers attributed improvements towards their competency, confidence, and qualifications to teach as a result of participating in UREs. Participating in UREs helped teachers better engage their students in the conceptual (understanding scientific knowledge and contexts,

modeling, and planning and carrying out investigations) aspects of scientific investigations, along with social (collaboration, communication, and evaluation of scientific information and results) aspects. Teachers found that engaging in UREs also helped them to connect lessons focused on scientific inquiry with applications that are relevant to the students and their communities.

The second study is focused on the BURET Teaching and Mentoring in URE Survey (BURET-TAMUS). Here, I developed and administered a survey to measure teaching practices, mentoring practices, and other aspects of the URE experience that undergraduate students experience while conducting STEM research. This was done to gain more insight on what integration of teaching and mentoring practices students feel are helpful towards their development and also to see if the extent of teaching and mentoring practices in UREs is influenced by other research factors. *Construct Response Modeling* was used as a foundation to build the survey instrument and several statistical models were employed to fit and analyze the survey data. We aim to use our data to study the multidimensionality of the teaching and mentoring constructs that we have defined and the latent variables that might be influencing them in UREs. Results indicate that undergraduate students in our sample who have research experience report high levels of support in terms of achieving research goals and social engagement (feedback, communication, and early project guidance) from their research mentors, but we found that the research factors that we tested for in BURET-TAMUS didn't seem to have much correlation with each other or some teaching and mentoring practices.

The third study featured in this dissertation is the development and execution of the BURET Bring out the Best in Your Undergraduate Researcher Workshop Series. This workshop series trains graduate students at UC Berkeley on how to work with and support undergraduate students conducting research in faculty labs. Over the course of several weeks, participants completed activities and engaged with workshop topics that are meant to help research mentors implement and plan their approach towards teaching and mentoring of undergraduate researchers. We emphasized the importance of effective mentorship and teaching of students through several educational and sociological frameworks to the workshop attendees. At the end of the workshop series, I recruited pairs of graduate students and undergraduate researchers working together in research for a study where I investigated how teaching and mentoring changed as a result of participating in workshop series and whether or not coaching could enhance the teaching and mentoring that graduate students were doing. The investigation was carried out via analysis of recorded interactions and materials submitted to the research team of a teaching or mentoring moment that occurred during their research experiences and through dedicated 1 on 1 coaching sessions with me. To see what was translating from the workshops and how teaching and mentoring was changing over time, we developed and utilized two instruments: BURET-CoTaM and BURET-NASER. The results indicated that much of the workshop content was being applied to actual teaching and mentoring practice by research mentors and that coaching sessions were helpful in getting research mentors to reflect on their approach, try new practices, and be comfortable discussing their teaching and mentoring.

From working on the BURET projects, I have been able to connect and work with students from many different backgrounds and experience levels. I have learned new

ways to approach teaching and mentorship in the classroom and in the research lab. I have gained skills to evaluate student learning and to reflect on my own teaching and mentoring. Through the interdisciplinary nature of my work, I have been trained to gather evidence that can be used to support chemistry students at other institutions and I hope to continue making contributions to student outreach and chemistry education.

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Preface

Undergraduate research experiences (UREs) are complex enterprises that require coordination, commitment, and care to ensure that they are successful for all parties involved. There are many types of UREs that differ based on different research environments, projects, expectations, and goals. In a typical URE, an undergraduate student is provided the opportunity to collaborate with a mentor (usually a graduate student or a post-doctoral scholar) on a research project that is taking place in a research faculty's laboratory (Coté, 2024). In this type of scenario, circumstances can quickly become complicated as all individuals that are involved in the URE are approaching the research collaboration with different motivations, goals, experience levels, and time-commitments.

Regardless, UREs have been repeatedly demonstrated to be beneficial for undergraduate students by increasing their academic and professional development (Adedokun, et al., 2012; Linn et al., 2015; National Academies of Sciences, Engineering, & Medicine, 2017; Rodenbusch et al., 2016; Russell, Hancock, & McCullough, 2007), motivating them to continue to pursue STEM opportunities (Estrada, Hernandez, & Schultz, 2018; Helix et al., 2022; Linn et al., 2015; Pearce, Brock, & Bunch, 2022; Thiry & Laursen, 2011), allowing them to pick up several new technical and intellectual skills (Linn et al., 2015; Sadler et al., 2010; Tan, Elkin, & Satagopan, 2022; Trott et al., 2020) and much more. The mentors for undergraduate students in UREs and even the faculty who oversee the research labs have also been shown to gain from UREs when preparing them for careers related to teaching or leading a research lab at an academic institution (Coté, 2024; Dolan & Johnson, 2010; Hall et al. 2018; Walkington et al., 2019).

Although the positive outcomes related to participation in UREs is already well supported by the literature, there are still a few aspects of UREs where more research is needed to help understand the specifics of how and why students are developing in them. For example, many different groups of undergraduate students engage with UREs for their own unique motivations and some groups, such as K-12 pre-service teachers, are not thoroughly studied so it is unclear what the impacts of URE participation are on K-12 STEM education (Auchincloss et al., 2014; Gitlin et al., 1999; Guilbert, Lane, & Van Bergen, 2016; Krim et al., 2019). Additionally, undergraduate students in UREs are mentored by individuals with different approaches and sets of teaching and mentoring practices which can affect the extent to which they benefit from the URE (Ann Mabrouk & Gapud Remijan, 2023; Hernandez et al., 2018; Estrada, Hernandez, & Schultz, 2018; Morales, Grineski, & Collins, 2024). More insight could be gained here in how to identify and distinguish between teaching and mentoring practices in UREs and how they are influenced by other external factors of the URE (Crisp & Cruz, 2009; Gershenfeld, 2014; Jacobi, 1991; Linn et al., 2015; Pfund, 2016). Moreover, there is room to study the impacts of training research mentors to support undergraduate students via direct intervention from STEM educators as research mentors often have little experience with being mentors before they are tasked with doing so (Amundsen & McAlpine, 2009; Ruben, 2020; Titus & Ballou, 2013). Lastly, the lack of homogeneity from UREs make it difficult to evaluate their effectiveness using a single approach or methodology (Coté, 2024; Crowe & Brakke, 2008; Helix et al., 2022;

Kardash, 2000; Krim et al., 2019). Therefore, research in this field must be prepared to develop various experiments, instruments, and analytical methods to adequately gain knowledge across many different contexts or scenarios.

To contribute more insights into the contexts and aspects of UREs that have had little research done in them and to accommodate the context-specific nature of UREs, the **Berkeley Undergraduate Research Evaluation Tools** (BURET) Project was developed. The goals of the BURET project are to: 1) Develop, refine, and test new tools/instruments to measure student learning, mentorship, and other outcomes while participating in UREs, 2) explore how undergraduate researchers (including K-12 pre-service teachers) develop an understanding of scientific practices and content and how they are translated to contexts such as the K-12 STEM classroom, 3) determine the impacts of teaching and mentorship training of URE research mentors. In this dissertation, three BURET research projects (one per chapter) are presented that aim to accomplish each of these goals and detail new tools/instrumentation that are used to investigate UREs in a novel way.

Chapter 1: The CalTeach and Berkeley Undergraduate Research Evaluations Tools (BURET) Collaboration: Investigating Undergraduate Research Experience Impacts on K-12 STEM Teaching (Project 1)

Introduction

Undergraduate research experiences (UREs) have been shown to be valuable to student growth across many academic and professional contexts. At the academic level, participation in UREs has led to observed and measured improvements to: disciplinary content knowledge, self-efficacy, scientific identity & confidence, research skills (such as critical thinking, problem solving, evaluation, and communication), aspirations to pursue higher education and training at the graduate and professional level, retention, academic performance, participation in future research experiences, motivation, integration into academia, and sense of belonging in their disciplines (Bower, 2010; Buchanan & Fischer, 2022; Corwin, Graham, & Dolan, 2014; Dolan, 2016; Eagan Jr. et al., 2013; Ebert, Dolphin, & Bischoff, 2023; Estrada, Hernandez, & Schultz, 2018; Guilbert, Lane, & Van Bergen, 2016; Harris et al., 2015; Kara & Corum, 2023; Krim et al., 2019; Lamanauskas & Augiene, 2017; Linn et al., 2015; Mordacq et al., 2017; Mraz-Craig et al., 2018; Pearce, Brock, & Brunch, 2022; Picardal & Sanchez, 2022; Rodenbusch et al., 2016). Beyond undergraduate education, students who have participated in undergraduate research have been observed to have an easier time being independent researchers at the graduate and professional level (Ebert, Dolphin, & Bischoff, 2023; Kara & Corum, 2023; Peterella & Jung, 2008; Windschitl, 2003). They are also more adequately prepared to enter more advanced and higher programs for their disciplines (Corwin, Graham, & Dolan, 2014; Kara & Corum, 2023; Peterella & Jung, 2008; Russell, Hancock, & McCullough, 2007). The enduring effects that UREs have on students continue to be explored by science educators via an assortment of evaluation approaches and investigations of outcomes that are specific to educational contexts (such as K-12 STEM teaching) that tend to be overlooked (Sadler et al., 2010).

The impact of UREs on K-12 STEM pre-service teachers (undergraduate students studying to be K-12 teachers) is particularly interesting because they are expected to apply and translate the knowledge and skills that they gained into the different academic context of the K-12 classroom (Krim et al., 2019). Many recommendations encourage science engagement in class to be analogous to science engagement commonly observed in research experiences. For many preservice K-12 STEM teachers, their exposure to research comes from working on a research project in a STEM faculty mentor's lab and/or an undergraduate research methods course (Schwartz et al., 2006). The National Research Council (2013) has recommended connecting K-12 STEM education with more authentic science learning experiences through inquiry-based learning. They describe inquiry-based learning as engaging students in the types of activities that scientists do such as making observations, generating research questions, collecting, analyzing and interpreting data, and

evaluating other research studies. In other words, connecting science teaching and student engagement to reflect how science is actually performed.

Thus, UREs should be ideal for engaging preservice K-12 teachers with scientific inquiry and scientific practices (Auchincloss et al., 2014). However, wide-spread implementation of teaching inquiry-based learning is challenging due to misconceptions on inquiry, lack of institutional resources, and lack of authentic research experiences to inform and build inquiry practices for K-12 teachers (Dobber et al., 2017; Grossman et al., 2009; Hanauer et al., 2006). One study demonstrated that pre-service teachers who had UREs involving the implementation of Model Eliciting Activities with a dedicated mentorship approach were able to better understand and relate to how novice learners of science approach inquiry-based scientific investigations and those pre-service teachers had increased reflection for adaptation of teaching practices for K-12 STEM teaching (Kara & Corum, 2023). We want to build upon the previous work of other researchers by identifying what aspects of teaching are affected by research done as a pre-service teacher and illustrating how teaching practices form and grow as they become active K-12 science teachers. Here, we ask how undergraduate pre-service teachers' participation in STEM research impacts their future K-12 teaching practices, including the use of inquiry-based approaches. We address the following research questions: 1. How do UREs influence the teaching of scientific inquiry in K-12 STEM by teacher education program graduates? 2. How do teachers perceive or describe the impacts of UREs on their K-12 STEM teaching?

Background: Pre-Service Teachers and UREs

A variety of studies have been reported that are centered on UREs for pre-service teachers and their impacts, outcomes, and recommendations for teaching practice. Schwartz, Lederman, & Crawford (2004), found that pre-service teachers in UREs that contained an explicit integration and teaching of the Nature of Science (NOS) developed practices related to NOS as reported from their collected journal reflections. In another study by Yen & Huang (1998), 10 pre-service biology teachers participated in an independent-study course where they engaged in a research project about the ecological physiology of tree frogs, and later reported development in how they viewed teaching with scientific inquiry. Namely, they gained increased content knowledge, collaboration skills, and a better understanding of science and how to consider problem solving when issues arise.

After pre-service teachers featured in Melear et al.'s (2000) study participated in a semester-long research course taught by practicing scientists, they developed scientific inquiry practices in experimental design, scientific iteration, scientific communication, and data interpretation. Brown & Melear (2007) reported that pre-service teachers that became apprentices to research scientists in their program gained experience with open-ended experimentation and learned valuable STEM content-knowledge and skills. Some of the pre-service teachers also reported that they felt a sense of project ownership over time and greater confidence as both a teacher and a researcher. It is worth noting that in Brown & Melear's study, the pre-service teachers indicated some difficulties in translating relevant aspects of their research experience to the classroom for a variety of reasons. Raphael et al. (1999) described a

study involving pre-service teachers doing summer research. They reported that these pre-service teachers used additional strategies to teach STEM, had greater connections with scientists to enhance teaching, improved STEM-content knowledge, demonstrated reflection on pedagogical practices, and had increased motivation and confidence to teach.

Other researchers have found participation in undergraduate research can result in increased feelings of self-efficacy for K-12 STEM Education for pre-service and active teachers (Ebert, Dolphin, & Bischoff, 2023; Pearce, Brock, & Bunch, 2022). Additional changes in teaching practice, learning outcomes, and implementation of inquiry in STEM lessons as a result of teachers participating in undergraduate research have also been reported and include: Improving K-12 student problem solving/critical thinking skills (Miranda & Damico, 2015), having K-12 students engage more with real world applications of science (Pop, Dixon, & Grove, 2010), increasing K-12 student STEM comprehension and literacy (Ragusa & Juarez, 2017) and having more K-12 student collaborations (Blanchard & Sampson, 2017). Some studies have also indicated, however, that there are some aspects of scientific inquiry and investigations common in research that are difficult to translate to K-12 teaching and more research is needed to measure certain K-12 student outcomes from pre-service teacher participation in research, and why specifically some shifts in teaching practices occur (Amolins et al. 2015; Bottcher-Oschmann, Ophoff, & Thiel 2021; McLaughlin & MacFadden, 2014; Krim et al., 2019).

The literature surrounding the evaluation of pre-service teachers that participated in undergraduate research and the outcomes they experience from research also indicate limitations. These include low sample sizes, fewer empirical studies, and more reliance on self-assessment and descriptive studies (Dolan, 2016; Kara & Corum, 2023; Krim et al., 2016). What is unique with evaluating research experiences for pre-service teachers is that studies often will use theoretical frameworks that are commonly used in educational research for the analysis, but the research experience itself will not be designed with those frameworks in mind which makes validation and reliability of results more difficult to demonstrate (Dolan, 2016). Pre-service teachers experience unique obstacles compared to other students as they are more motivated to teach than to do research, and they may have difficulties perceiving research as something that would be useful to their teaching practice (Guilbert, Lane, & Van Bergen, 2016). This causes fewer pre-service teachers to take the first step to engage in research. While they more positively perceive research after doing their first research experience, more work needs to be done to make sure that research experiences are implemented and provided to pre-service teachers in a fashion that is suitable to their needs and the needs of teacher education programs (Gitlin et al., 1999; Guilbert, Lane, & Van Bergen, 2016; Ozmutlu, 2022; Kara & Corum, 2023). For many preservice K-12 teachers, a common exposure to scientific research comes in the form of a research methods course in the field of education taken in their undergraduate programs.

In our study, we address some of the gaps and limitations in evaluating UREs for pre-service teachers and resulting translation to teaching practice by recruiting participants from graduates of an undergraduate teacher education program where students are required to engage in research. This program has also introduced many of the theoretical frameworks that are at the foundation of our research study into the URE

program and expectations for their pre-service teachers. We provide a unique contribution to the literature by further illustrating important connections between scientific inquiry in the STEM research lab and in the K-12 STEM classroom for active teachers who conducted research as a pre-service teacher.

Theoretical and Other Frameworks

A Framework for K-12 Science Education

Several theoretical frameworks informed the design of our study. The first is outlined in *A Framework for K-12 Science Education* (National Research Council, 2012), which describes how teachers engage students with inquiry. The National Research Council (2013) uses the *Framework* to present a set of common standards used by dozens of states in the US as a set of disciplinary core ideas and cross-cutting concepts that complement a set of NGSS Science and Engineering Practices (SEPs). These three dimensions are combined when teaching scientific material so that students properly develop understanding and skills for inquiry.

Next Generation Science Standards and Common Core for Mathematical Practices

The NGSS SEPs are useful and relevant to examining the impact of UREs on inquiry-based instruction as they include things such as asking questions, developing models, analyzing data, and communicating scientific information. We also drew from the Common Core Standards for Mathematical Practices to understand math teacher implementation of inquiry-based instruction. These are a set of practices that are important to proficiency in mathematics across different grade levels from K-12. They include problem solving, proofs, abstract reasoning, modeling, constructing rational arguments with empirical evidence and more. The NGSS SEPs share similarities and are aligned with the Common Core Standards (National Academies of Sciences, Engineering, & Medicine, 2017; National Research Council, 2012; National Research Council, 2013), such that in a typical science or mathematics lesson or unit, there is often a significant overlap between the two sets of practices. Thus, we considered both sets of practices when carrying out this work.

Pedagogical Content Knowledge

We also consider the Pedagogical Content Knowledge framework (PCK) to understand teacher's descriptions of inquiry-based teaching in their classrooms. PCK is a unique form of knowledge that stems from the integration of subject knowledge and pedagogical strategies to most effectively teach disciplinary content. (Gudmundsdottir & Shulman, 1987; Shulman, 1987). The PCK framework helps to illustrate how teachers adapt their instruction over time, take into account the needs of the students, and make decisions on their pedagogy which allows for researchers to qualitatively analyze impacts of teaching (Ball, Thames, & Phelps, 2008; Hill, Ball, & Schilling, 2008). The

PCK framework is appropriate in this context, as reinforced content knowledge is commonly self-reported by teachers who participated in UREs, who were often tasked with communicating full understanding of their projects in research presentations and later integrating the teaching of STEM content and practices in their teaching. For further understanding of the integration of science content and practices, we also relied on the Knowledge Integration framework. This learning science framework emphasizes that coherent understanding occurs when students make deep connections between their prior and new ideas. KI specifies four key components that support student learning (Linn & Eylon, 2011; Linn, 1995; Linn, 2000; Songer & Linn, 1991;) - eliciting prior student ideas, discovering new ideas, distinguishing between competing ideas, and consolidating ideas into a coherent narrative. The process of conducting research generates knowledge in a way that parallels the KI framework (Helix et al., 2022; Linn et al., 2015). In this study, it will help us to understand the connection between STEM practices that K-12 students engage with in the classroom and the teaching practices of their teachers.

Cognitive Domains of Inquiry and Research Mentoring Practices

We supplemented the NGSS and Common Core standards with the BURET-TaM instrument designed to assess teaching and learning in UREs (Coté et al. 2026). BURET-TaM itself was adapted from the Cognitive Dimension of Inquiry (Furtak et al., 2012; Duschl, 2008). The Cognitive Dimension of Inquiry is a conceptualization of inquiry that consists of four domains (Conceptual, Epistemological, Social, and Procedural). These domains of inquiry, respectively, include conceptual structures of scientific reasoning, epistemic components for scientific knowledge, social interactions for scientific communication, and procedural methods for scientific discovery in investigations involving natural phenomena. This instrument helps to identify different ways that teachers engage students with scientific inquiry in their lessons and what students are actually doing as a result of said engagement.

Finally, because of the importance of mentoring in undergraduate research and the K-12 classroom, we include frameworks related to student mentoring in our study. The effectiveness of student research mentoring can have a sizable influence on how students engage with and benefit from UREs as we have demonstrated in our research group's prior work (Coté, 2024; Coté et al., 2025). From the work of Coté 2024 and the 10 Salient Practices of Undergraduate Research Mentors (Shanahan et al., 2015; Walkington et al., 2019), we have included a set of practices that have led to effective research mentoring. We propose that some of these practices are translatable to the classroom, which could potentially help enhance some aspects of K-12 STEM teaching, such as dedicated pre-planning and teaching of technical skills.

The aforementioned frameworks create the theoretical foundation of this work, aid in the design of the coding scheme for interview data, and contextualize interpretation of the data. These frameworks directly relate to teaching practices, student mentoring, integration of scientific knowledge and skills, engagement with inquiry, and scientific practices/mathematical standards that should be part of every STEM learning environment

Methods

Research Recruitment

We interviewed 24 graduates of an undergraduate teaching credentialing program at a large research university on the West coast of the United States, over the course of 2019 to 2023. The teacher education program allows students to complete a minor in Science and Math Education and receive a state-accredited secondary science and math teaching credential simultaneously with their undergraduate STEM degree. Students who complete this program are exposed to courses that focus on educational theory, pedagogical content knowledge, promote diversity, equity, and inclusion, engage in UREs, and complete student teaching placements in local math and science K-12 classrooms. Therefore, these graduates were an ideal sample group to study as they had research experiences as undergraduate pre-service teachers, and were actively involved in STEM teaching soon after doing research.

Students participated in a course-based undergraduate research experience (CURE) during their 2nd or 3rd year of the program, where they engaged in a research project within a faculty laboratory, either for a 5 week duration in the semester or for an 8 week duration in the summer session. At the end of the CURE, students present their research via a public poster showcase on campus. Soon after participating in this CURE, pre-service teachers begin their teaching placements and start practicing pedagogy with actual students. The expectation is that this research experience will help teachers engage in scientific inquiry before practicing their pedagogy, and this participation will have some translation and observable effects for how they engage K-12 students in STEM.

A member of the research team with familiarity with recent graduates of the program reached out to identify which of these graduates were active teachers and were able to volunteer/consent to the research study. The graduates were also incentivized to participate in the study through compensation in the form of a \$250 Visa gift card. Our study procedures were approved by the University of California, Berkeley Committee for Protection of Human Subjects, Protocol #2016-02-8360. Individuals that were interested were sent a consent form followed by a pre-recruitment survey via Qualtrics (UC Berkeley).

Study Compensation

Teachers who were recruited for the study were compensated to participate in the study through a \$250 Visa gift card. Gift cards were provided after completion of their interview.

Recruitment Survey and Interview Protocol

The research team prepared a semi-structured interview protocol (Table 1.1). The questions on the interview protocol targeted how the participants made connections

between their research experiences and teaching, how they implemented scientific inquiry in their lessons, and how they incorporated NGSS scientific and engineering practices. A short survey was administered to get information on participants' undergraduate research experiences, their teaching, and their recent teaching experiences, and some demographic information. The pre-survey collected this data from each participant to provide the research team with some additional context before the first interviews. The participants consisted of middle and high school teachers who taught for grade levels 6-12. A chart that contains a breakdown of the different STEM subjects that the teachers had taught is in the *Appendices*.

Table 1.1. Interview Protocol

#	Question Sets
1	If you could have a 5-minute video clip of the lesson you have just taught, what would you choose and why?
2	Which Next Generation Science Standard Science and Engineering practice(s) do you use most and least frequently? How do your students make connections between the practices? Can you give examples?
3	Can you walk me through an inquiry focused lesson you have taught? In what ways does the lesson you just taught be considered inquiry?
4	Can you walk me through an inquiry-based lesson you felt was effective at promoting equity and access for your students?
5	In what ways did your research experience in [REDACTED], or other undergraduate research experiences shape your current teaching? What did you learn from this research experience?
6	Where in the scope of topics that you teach, have you been able to build opportunities for your students to work with data?
7	In what ways, if any, have considerations of social/racial justice played a role in your teaching/lesson design? In what ways, if any, have considerations of social and racial justice played a role in your teaching/lesson design with respect to your work with guiding students to use data this year?

Interviews with each participant took place on Zoom and the majority of interviews were 30 to 60 minutes in length. A transcript from each interview was collected and formatted for qualitative coding. Out of 24 participants, 4 were interviewed a second time over the course of a few years which led to a final transcript total of 28. Note that unless otherwise stated, analysis in this study was completed with just the first transcript of each participant (n=24).

Development of Coding Scheme

A qualitative coding scheme was developed to categorize and identify data in the interview transcripts for further analysis. Due to the significance of our theoretical frameworks during the planning and organization of this research study and the more grounded, less abstract, data elucidated from our interview protocol and sample group, we opted to design a qualitative coding scheme that would allow the research team to conduct both inductive and deductive coding. Five coding categories were developed: *Implementation of Inquiry*, *Scientific Practices*, *STEM Mentoring*, *Equity Incorporation*, and *Insights from Research*. Each coding category is described in Table 1.2. In total there were 46 codes in the qualitative coding scheme from the 5 categories. A full breakdown of the coding scheme and each individual code is provided in the Appendices.

Table 1.2. Coding Scheme Categories and Descriptions

Category	Description
Implementation of Inquiry (14 codes)	Teachers reflect on their inquiry-based teaching and how they implement/perceive inquiry
Scientific Practices (16 codes)	Practices utilized in class that mirror those of professional scientists and engineers
STEM Mentoring (3 codes)	Actions that a teacher can perform to serve as a STEM role model or mentor
Equity Incorporation (5 codes)	Codes centered on how teachers promote educational equity and awareness of social and racial issues
Insight from Research (9 codes)	STEM or teaching practice insight gained from their research experiences

In the initial stages of codebook development, more codes were developed than the ones described above. When we considered the lack of homogeneity that was to be expected in each teacher's experience in the classroom and in research, we felt it necessary to establish many broad codes so that we could more easily identify common trends in the data. We attempted to design codes that would capture aspects of research that could be commonly expressed across a wide range of experiences. After a few coding sessions, we observed that many of the codes were never applied so we included their characteristics in with other codes if appropriate, while others were

deleted entirely. Thus, we were left with codes that were either crucial elements of theoretical frameworks/prior research instruments or were related to our prospective interview data (i.e., NGSS, BURET-TaM, *Insights from Research*). The categories were finalized when an agreement regarding code clarity, category representation, and proper fit with our interview protocol was reached for each category by the research team.

The *Implementation of Inquiry* category encompasses codes relating to a teacher's implementation of scientific inquiry, i.e., teaching practices or teaching goals, their perceptions/reflections of what scientific inquiry is, and any barriers to this implementation. Codes relating to teaching practices were adapted from the BURET-TaM instrument that was described in the Theoretical Framework section. It's important to note that while we assumed a broad definition of scientific inquiry for the purposes of the teacher interviews, we argue that scientific inquiry must involve student engagement in methodological scientific investigations via the Next Generation Science Standards (See *Theoretical and Other Frameworks* Section) and be actively guided by instructor teaching practices that elicit the domains from the Cognitive Dimension of Inquiry. This category contained 14 codes.

While there are some similarities between engagement of scientific inquiry for undergraduates doing research with mentors and students taking part in scientific lessons guided by teachers, we did make some alterations to what constitutes the different domains of the Cognitive Dimension of Inquiry when adapting them to an interview coding scheme. For instance, we changed student actions or ideas into those that would be reasonable to expect in the setting of a typical K-12 science classroom. In this setting, scientific inquiry lessons may only last an hour or so, while more dedicated scientific investigations that undergraduate students participate in could last several weeks. Examples of these adaptations can be located in the code descriptions for the TP-Dom codes in the Appendices.

The *Scientific Practices* category represents codes for student engagement in various scientific and engineering practices that are used in a typical scientific investigation as adapted from the Next Generation Science Standards. In addition, we included codes that represent student actions relating to scientific discussion, iterations, or reflections. This category contained 16 codes.

The *STEM Mentoring* category features codes adapted from Coté (2024) that correspond to mentoring practices that teachers utilize in the classrooms that may also be experienced by them in their UREs. This category contained 3 codes.

The *Equity Incorporation* category contains codes for instances when teachers report examples of incorporation educational equity, issues of social and racial justice, and/or socioeconomic barriers to teaching in STEM. Some of these factors could complement/complicate scientific inquiry in K-12 classrooms and help lead to a deeper interpretation of the interview data. This category contained 5 codes.

The *Insights from Research* category is composed of codes that help highlight interesting components of each teacher's URE. Due to the lack of homogeneity that is expected in a typical URE, we opted to design some codes based on research takeaways that would be general and commonly experienced across different contexts so that we may attempt to draw thematic connections between the student research experience and the approach to science instruction/inquiry that is taking place in the

present. We also included a few codes that were directly related to research experiences helping one feel more prepared and motivated to become a practicing science teacher. A couple of codes were later introduced to categorize negative experiences with undergraduate research or if the teacher felt that the research had no application on their current instruction. This category contained 9 codes.

As we grew close to reaching a consensus on the substance of the coding scheme, we performed additional coding sessions to measure intercoder reliability between members of the research team through the use of the Cohen's Kappa parameter (Cohen, 1960; Nili et al., 2020; Cheung & Tai, 2023). We report a Cohen's Kappa of 70.9% between 2 members of the research team.

Data Collection

After we had performed multiple rounds of preliminary coding on each of the 28 interview transcripts to obtain acceptable intercoder reliability between different members of the research team, we carried our data and coding scheme into MaxQDA (2022 Student Version). We carried out a final coding session of all of the interview transcripts to prepare for an in-depth analysis. In all of our coding sessions, we defined each coded sentence of a transcript as a single unit.

For our analysis, we measured coding frequency by tabulating all of the separate codes that were applied to each document. We measured coding frequencies across all the used codes in each coding category in the 24 transcripts that correspond to unique teachers to identify initial trends and connections between individual codes that could be uncovered.

Data Storage

Interview data in this study was stored on a UC Berkeley licensed Box account. The data is deidentified and organized by creating a unique, random codename for each participant. A key was created that links the random code names to identifying data. The key is stored and kept secured on Box separately from the rest of the data. The researchers are the only individuals who have access to identifying data on Box. Data and keys stored on Box are to be deleted 3 years after completion of this study.

Limitations

Our study contained a relatively small number of participants. Many of these participants were students at the same institution and were part of a few different cohorts of the teacher credentialing program at that institution. Thus, those interested in performing a similar study should also consider implementing control groups based on other institutions that may not emphasize UREs in their pre-service teachers or with teaching credentialing programs that have pre-service teachers with a wider range of socio-economic statuses.

The data we collected is limited to interviews that we conducted with each of the 24 teachers. Much of this data is based on the specific questions that were prioritized for inclusion in our semi-structured interview protocol. This type of data would benefit

from further validation for similar studies in the future. Further validation can be obtained through classroom observations of STEM teaching, and additional interviews with participants where they can verify what they mentioned in their original interviews. Preliminary exit interviews or written reflections with pre-service teachers who commit a study such as this one long term after they complete their UREs could be insightful to see what they feel they will take away from it with respect to STEM teaching.

It would also be of interest to conduct additional interviews over time with more teachers after research and at different stages of being a pre-service teacher to obtain further insight into how they are developing their scientific inquiry and teaching practices and how they connect their UREs to said development. While we made sure to have a focus on drawing connections between teaching practice and undergraduate research, it is possible that other factors in the teaching credential programs are also contributing to the results we have obtained. We noted that some teachers in our study sample tended to have already understood or “solidified” their approach to science instruction from other components of their teaching credential program before they engaged in research. As we did not recruit participants in this study until after they had become active teachers for two years, we were not able to control or identify any other formative experiences in the teaching credential program that might have influenced their current teaching.

Results

We sought to develop insight into how teachers integrated their undergraduate research into their teaching of K-12 students. We first used key transcript excerpts from our teacher sample to help set a foundation/framework for interpretation of our data. As our research questions mainly related to understanding how pre-service teachers are engaging with and implementing scientific inquiry from their undergraduate research, we focused on developing codes in three categories: *Implementation of Inquiry*, *Scientific Practices*, and *Insights from Research*. We also coded for areas important to both undergraduate research and teacher education: *STEM Mentoring* and *Equity Incorporation*. Table 1.3 below tabulates coding frequency of each code category as a percentage of the total codes used in 24 teacher interviews. As illustrated in Table 1.3, we found that *Implementation of Inquiry* and *Scientific Practices* had the highest coding frequency of the five categories at 41% and 34% respectively.

Table 1.3: Code Frequency, Code Descriptions, and Code Totals by Code Category

Code Category	Description	# of Codes in Category	Coding Frequency in Responses
Implementation of Inquiry	Teachers reflect on their inquiry-based teaching practices and how they implement/perceive inquiry	14	41%
Scientific Practices	Practices utilized in class that mirror those of professional scientists and engineers (and named in the NGSS)	16	34%
STEM Mentoring	Actions that a teacher can perform to serve as a STEM role model or mentor	3	3%

Equity Incorporation	Codes centered on how teachers promote educational equity and awareness of social and racial justice issues	5	11%
Insights from Research	STEM or teaching practice insight gained from their research experiences	9	11%

We identify and describe below four themes centered around these coding categories. For each theme, we provide an overview of the “main idea,” followed by both quantitative and qualitative evidence supporting the theme.

Theme 1: UREs Impact K-12 STEM Teaching by Enhancing STEM Content Knowledge & Student Mentoring

The codes from the *Insights from Research* category were designed to highlight interesting and generalized components of teachers’ UREs. Areas of note that emerged from the coding were content knowledge, research procedures, and awareness of social and racial issues. Figure 1.1 describes coding frequency of codes in the *Insights from Research* category across all of the 24 initial teacher transcripts. See the *Appendices* for a full description of each code in this category.

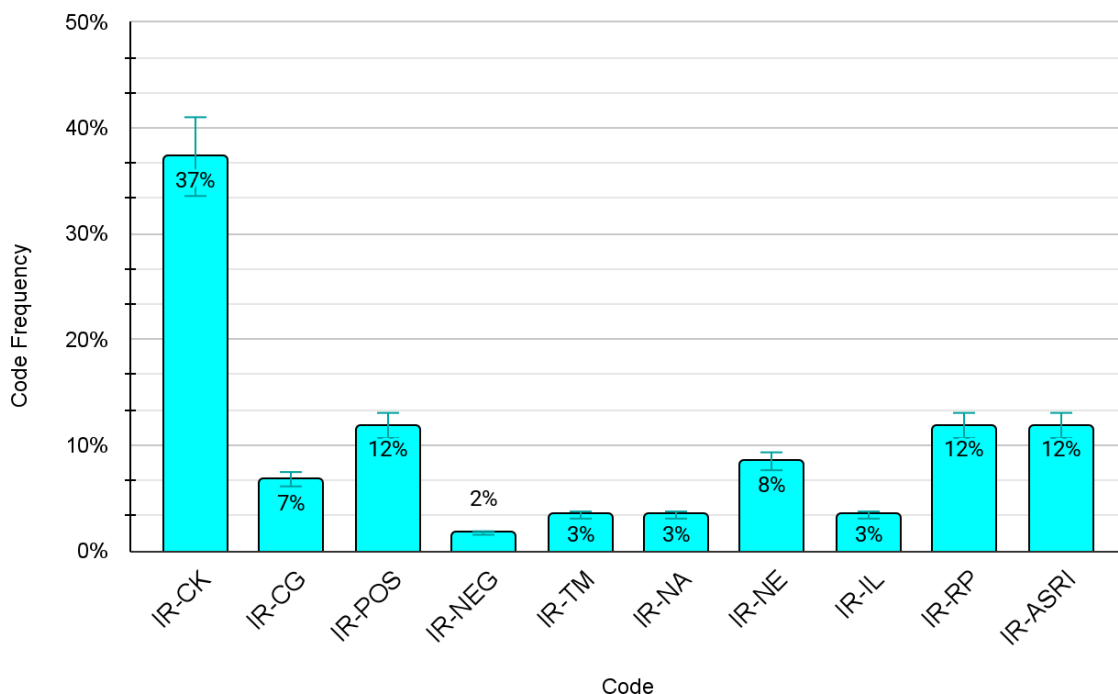


Figure 1.1. Coding Frequency (number of times a code was used relative to the rest of its coding category) for Insights from Research (IR) codes (n =24). Codes include IR-CK (IR-Content Knowledge); IR-CG (IR-Confidence Growth); IR-POS(IR-Positive Outcomes); IR-NEG(IR-Negative Outcomes); IR-TM(IR-Teaching Motivation); IR-NA(IR-No Application); IR-NE(IR-No Research Experience); IR-IL (IR-Importance of Literature); IR-RP (IR-Research Protocol); IR-ASRI (IR-Awareness of Social and Racial Issues).

Many responses contained broad recollections of UREs, yet we found them to be insightful. The majority of teachers, when prompted to describe their UREs and how the research experience affected their science teaching, attributed the content knowledge that they gained from the experience as the most impactful (IR-CK). For example, Teacher A, an AP Biology teacher, described a moment to us where they were able to confidently navigate academic literature for their class as a result of what they had learned doing undergraduate research:

And so if I wanted to have some information on how the Gulf dead zone was going to change this ecosystem, I needed to find some data for that. And so I poked around on the Internet until I found someone's master's thesis where they had been recording that they were. I think that they were specifically looking at benthic invertebrates. And just like one of their figures was really nice and was interpretable by ninth graders. And so I took their graph and I brought it into my class. We discussed how the food web that we had created would be impacted by the Gulf dead zone. And I think that if I had not had the research experiences that I had, I probably would not have felt confident to snoop around the master's thesis until I found what I wanted.

On a more psychosocial level, UREs helped teachers feel more prepared and confident to teach their sciences. IR-CK was by far the most used code in the Insights from Research category in our data and we have numerous examples of content knowledge having a direct effect on teaching. Any teacher who feels prepared and confident to teach is able to engage their students with more creative materials, objects, or teaching approaches. Below, Teacher CO, talks about how UREs have allowed them to learn new tools and software for crafting things that can be incorporated during class.

I was in an engineering lab and we were looking at different things. We were building different structures to figure out how these lattices would improve airflow and efficiency, especially in non air-conditioned places. It was really interesting. Although I feel like the main thing that I learned from it is how to do CAD design and that's something I'm really interested in doing for 3D printing. That's something I'm really interested in incorporating into my class.

Other responses from teachers recounted positive teaching outcomes or experiences (IR-POS) as a result of participating in a URE. For example, Teacher A18, a high school physics teacher, below shared how their research experience helped them communicate the methodological nature of research to their students (IR-POS, IR-RP):

It also helps me recognize the importance of statistics, like we focus a lot on the algebra, calculus side of physics, but a lot of the discoveries that we make, a lot of the breakthroughs that physicists make are actually from lab sciences where statistics are some of the more prominent forms of math that you have to know. So I try to incorporate those in my lessons or have opportunities for them to analyze and interpret data...

Teacher T12, who teaches AP Biology, mentioned how their research experience taught them the value of informal science learning and observation-based activities:

I did research on the implementation of a specific professional learning model for outdoor learning experiences, something that I'd never thought about before. There are schools out around the United States that primarily focus at least half time. They focus on grabbing students and pushing them outside to have these wonderful experiences of observation, of measurement, and just enjoying nature. I learned about informal science learning, which I didn't implement as much in my pedagogy now that I think about it. But I wish I did more.

In Teacher N7's case, their research experience helped them with designing lesson plans and identifying classroom resources for their high school environmental science class:

Lesson planning is something that I want to make sure is engaging and fun. But I also want to have that work life balance. Whereas this showed me so many different platforms where I don't have to create all my curriculum from scratch. Or creating my lesson plans from scratch and then also collecting data from students. I think those are the two major things, it was just getting a really great curriculum and platforms that I can use within my classroom. And then two is collecting data in my classroom where it's not biased

because I'm someone that I really connect with my students

UREs are not homogeneous, including among our sample. Students are expected to have different takeaways from their research experiences for a variety of reasons. However, it is worth mentioning that several teachers indicated in their interviews that they either had no recollection of their UREs or felt that their research experience was not really impactful for their teaching (8% were coded as IR-NE and 3% as IR-NA). For example Teacher B12 felt that their research experience had minimal impact due to the challenges with getting started with applying teaching practice as a new high school teacher in integrated mathematics:

I don't think it has shaped it much because I haven't really had the time to like to check my lesson plans with things like UDL and reiterate my lesson plans and stuff because of just how much is expected of us as teachers. Especially as a first year teacher making all this curriculum, a lot of time from scratch or like putting stuff together and so yeah. Mostly I wasn't really able to think about it deeply... the research was more like an idealized world where teachers would get the resources to think about these things.

As student mentoring is generally considered important for student learning within UREs and by teacher education programs, we paid attention to any specific ways the teachers in our sample would translate different mentoring practices in their classrooms. Student mentoring, the intentional act of supporting students psychosocially or in their academic development, is important to acknowledge because for many students their K-12 science courses are their first exposure to science and thinking like a scientist. Effective mentoring can help students feel less overwhelmed, with a greater sense of belonging, or more confident to engage in science and thus, scientific inquiry.

The *STEM Mentoring* category codes were developed from the research team's prior work (Coté, 2024). The EMS-1 code was used for mentoring practices related to academic/career goals, professional development, and physically doing things related to entering the scientific community like going to conferences and pursuing higher education or professional science internships. Teacher CL, in their interview, provided one example of EMS-1. In this case, they describe how they attempt to connect scientific lessons to potential career options for students.

But then also with just the summer research, we put a lot of emphasis that what I was doing in the classroom had a reason. It's not just this crazy thing that you just do to learn like there are real people who do research and do that stuff. So in my classroom, I try to open up different career options to kids like if this is something that interests you, you can continue to learn about it and do it in the future. And I also know the importance of providing evidence and analyzing certain things because if I can't support my ideas then my opinion doesn't really matter.

The EMS-2 code was used for mentoring practices related to psychosocial support, community-building, inclusion, getting to know their students better, and building student's self-confidence related to STEM subjects such as with Teacher KY in environmental science below.

Especially because, I just feel like, especially because you know a lot of students, especially POC students are told from a really young age that science isn't for them or they're not good at math and science and stuff so I just wanted to um, yeah... Give them as much opportunity as possible to do little science things so they don't, you know, like hey this for you, you're really good at this, yeah.

Not every transcript featured concrete examples of mentoring in our data sample. Out of the 14 teachers who were coded with an EMS code, the vast majority were represented by EMS-2. In addition, for both EMS-1 and EMS-2, we note a lack of

explicit integration between the mentoring practices that are characteristic of these two codes in our data and in what teachers shared with us about their research mentors. We observed that teachers provided little detail on their specific interactions and dynamics with their research mentors, but often highlighted their expertise and things they learned from them.

Theme 2: Teachers Implement Scientific Inquiry via Distinct Teaching Practices Stemming from their Research Experiences and the Domains of Inquiry

The *Implementation of Inquiry* coding category, the most frequent among the 5 major categories, contains codes relating to a teacher's implementation of scientific inquiry, i.e., their teaching practices or teaching goals, their perceptions of what scientific inquiry is, and any barriers to implementation. In addition, the category represents codes relating to distinct teaching practices such as TP-DomS, TP-DomE, TP-DomP, and TP-DomC, adapted from each of the 4 domains of Inquiry (Coté, 2024; Furtak et al., 2012). As a review, the conceptual domain, DomC, describes teaching practices or actions that engage students with science as a body of knowledge, including scientific facts, theories, and principles. The procedural domain, DomP, describes teaching practices that utilize the methods of discovery. The epistemic domain, DomE, describes teaching practices that engage students in learning about how scientific knowledge is generated, through their direct involvement with scientific investigation. The social domain, DomS, describes teaching practices that engage students in class discussions with group members about the project, research, or work, in a way that allows the student to “work things out,” make an argument, or reach a decision. We also investigated whether connections existed between the teaching practices that were reported by each teacher, and how they perceived scientific inquiry through the following 3 codes (II-SC | Inquiry Impression - Student Centered; II-AS | Inquiry Impression - Authentic Science; II-TG | Inquiry Impression - Teacher Guided). See the *Appendices* for a full description of each code in the category.

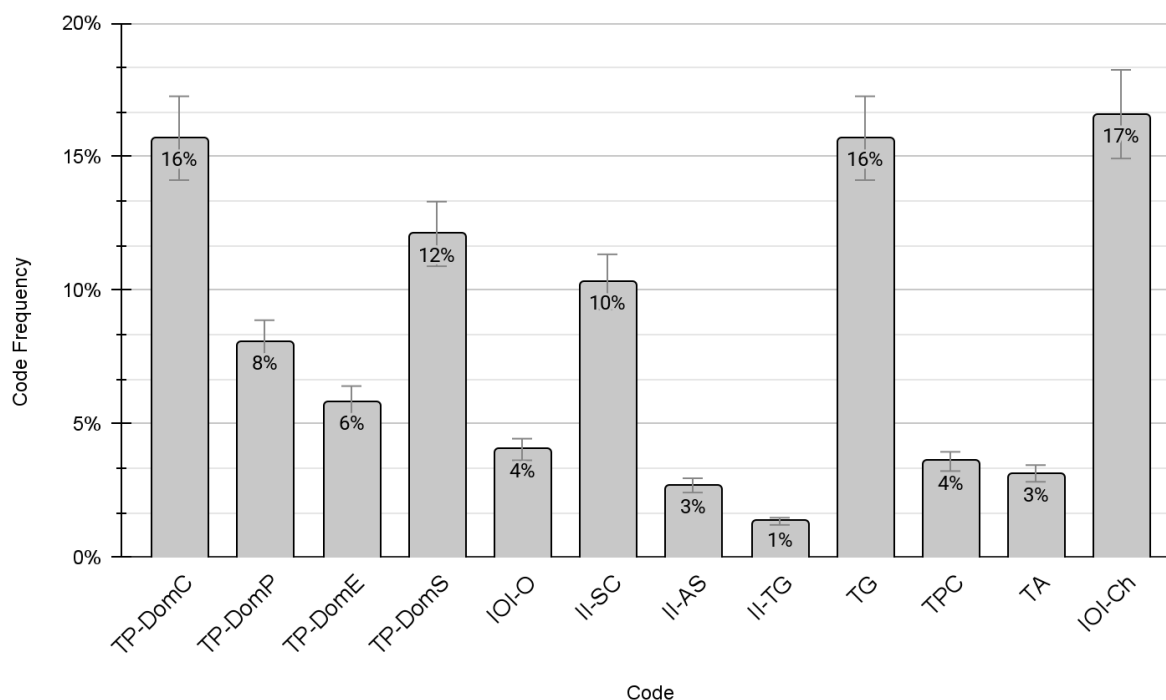


Figure 1.2. Coding Frequency (number of times a code was used relative to the rest of its coding category) for Implementation of Inquiry codes (n =24). Codes include Teaching Practice - Conceptual Domain (TP-DomC); Teaching Practice - Procedural Domain; (TP-DomP); Teaching Practice - Epistemological Domain (TP-DomE); Teaching Practice - Social Domain (TP-DomS); Implementation of Inquiry - Observations (IOI-O); Inquiry Impression - Student Centered (II-SC); Inquiry Impression - Authentic Science (II-AS); Inquiry Impression - Teacher Guided (II-TG); Teaching Goal (TG); Teaching Practice Change (TPC); Teaching Assessment (TA); Implementation of Inquiry - Challenge (IOI-Ch).

Figure 1.2 depicts the Coding Frequency of codes in the *Implementation of Inquiry* category across all of the initial 24 teacher transcripts. See the *Appendices* for a full description of each code in this category. We found that each of the TP-Dom codes, with the exception of TP-DomE, were used frequently and by at least 18 of the teachers in our sample. Below we provide examples from transcripts for each of these codes. We note that these practices were often mentioned and used together when teachers discussed their lesson plans related to scientific inquiry.

Teacher JM introduced new concepts in their high school chemistry class through simulations, computer software, and videos which would be classified as TP-DomC.

And then I think about my favorite activity... learning about what are the different forms of energy. And they're able to do that with ... a Gizmo simulation where they were looking at kind of like a map or something like that, where they had like energy in different forms. So that's just first for identifying the types of energy and then they had to start thinking about modeling energy transformations in real life. Just identifying where there is an energy transformation and then we did the energy density of different fuels.

Students in Teacher MC's high school mathematics class were exposed to TP-DomP through working with data sets obtained through online sources that met their interest, and creating visual figures with the data.

So one of my last projects with my classes was just working on using a website called Kaggle, which has a lot of open source data sets. And I gave them just like 20 minutes to just explore and see what you can find on there and sort of like play around with the site and people found all sorts of different things, or someone who's like, "Oh Skyrim weapons!" And someone else who's looking at surgery rates or something. ...I told everyone to pick one thing that they wanted to focus on for the project and I worked with them to

sort of take this raw data set, import it into Google Sheets, pick two columns that they wanted to determine were independent or dependent and then find ways to aggregate all the data together using some Google Sheets commands.

TP-DomS was demonstrated in Teacher N7's recount of how they allow students to communicate what they have learned in class.

They had to make their own advertisement to make kids not vape, so an anti-advertisement. They got to make it in any way they wanted. They had to research it, they had to put their own data into it. And they also got to choose if they wanted to present it in class or if they wanted to make a video. Or add a poster for extra credit. So I like to give them a lot of options. So for kids anytime it's inquiry based, they like it a lot more because they get to choose what the topic is or they get to choose the specifics or how it's mapped out. I definitely try to, whether it's a poster or some sort of project, I make the question really broad.

As an example of TP-DomE, the least frequent of the 4 domains, Teacher T12 encourages students to evaluate scientific knowledge and arguments for themselves.

So I would say that lots of activities in my classroom involve evaluating claims, evidence, and reasoning. I always teach, I told my students on the first day, don't ever take your knowledge for granted. And don't ever take someone's knowledge without a grain of salt. Right? And so that essence of asking questions and questioning, both authority and things that everybody just accepts. That's the spirit of being a scientist and the spirit of being a student to always question.

There were 3 codes in this category that correspond to 3 perspectives for how to teach scientific inquiry. They are the student centered (II-SC), authentic science (II-AS), and teacher guided (II-TG) codes. II-SC was the most reported of these 3 within our teacher sample. For example, Teacher RC expressed they felt like their high school physics students needed to independently engage in scientific investigations.

[Inquiry involves] investigations, where a student can choose their experiments and then go from there... So this was like a segue into building their own parachute models and then their investigation. And then they like to start to piece together like how parachutes work and what are the physics behind it, and then we revisit the video. We revisit their parachute models that they've been marking up and they try to add more things to it. This is stuff that we've learned for the past month that applies to this grounding phenomena. At the end of the unit they revisit it for the third and last time and they try to sum it all up together and come up with a more whole explanation for what exactly happened and why.

Similarly, some teachers, such as Teacher CL felt like the students should be the main drivers of their learning with minimal guidance from the instructor when teaching integrated science.

But just problem solving, critical thinking, and putting a lot more of the work on the students rather than the teacher. I mean even throughout [REDACTED] it was always hands-on activities and not lectures anymore. So definitely having the students drive their learning with maybe just a couple guiding questions if they're stuck. But I know that I try to have a lot more hands-on activities where they are doing the thinking and trying to problem solve.

19 teachers reported challenges or obstacles with implementing scientific inquiry in their classrooms (IOI-Ch), for example, that scientific inquiry was beyond their lesson plans, uncertainties on how to approach inquiry, or feeling like they don't have the adequate resources or materials for inquiry. In Teacher A18's case, they note an example of being uncertain on how to engage with scientific inquiry.

The main barrier that I have encountered is being able to guide the inquiry effectively without being too helpful. For example, when students in inquiry activities are asking questions, but like, you know, not the right questions or like their questions aren't leading them down the path that you had intended them to or the path that the activity was assigned to lead them down, it is difficult is to step in and guide the student towards the path without being like, oh, you drifted away. It can be difficult to find the balance of not being too helpful.

While in Teacher T12's experience, they felt that the AP curriculum and supplies limited the extent to which they could have students engage in scientific inquiry.

I think especially the AP curriculum, it really funnels students into these 8 to 12 big experiments such as the beetroot experiment, et cetera, et cetera. And it doesn't allow for a time outside of that to develop inquiry and to chase their own scientific curiosity, and journey. I think finance is the other. I used my own money to buy those miracle berries. Giving students the supplies that they need to create something and investigate something that they actually care about.

Teacher G20 felt that the shift or change in their teaching approach for high school physics toward inquiry would be difficult at this stage in their career.

Since I'm a new teacher, I find myself having a hard time letting go of the power. I really like telling my students what to do, and so in an investigation you have to be very strategic in what you tell them and what you let them do, which is what is so powerful and so fun, and so memorable about investigations....But unfortunately, it's not something I really implemented as an educator myself yet.

Teachers also shared personal teaching goals (TG) that they had for their next year of teaching, some of which included more conscientious efforts to engage students in scientific inquiry. Once again, from Teacher G20, we see some reflection on what type of projects would be suitable for scientific inquiry engagement for their students.

I think it definitely makes me more willing to try it [inquiry] as an educator because I've literally seen it work and I've been the student on the receiving end as well. And so for this coming year, my summer project is actually to incorporate more projects, and now definitely ones with more equity in them and more socially motivated projects.

We also asked for instances of lesson plans and/or teaching practices that featured elements of educational equity or awareness of social and racial issues. Here, we define educational equity as the idea of fairly distributing educational resources and services to students, particularly for typically low-resource schools and for those from historically underserved students in order to address or compensate for known disparities (EQF). Social justice is defined here as the belief that all citizens in a society should be treated equally in social and legal contexts, have fair access to opportunities and resources, and not be disproportionately affected or marginalized by laws, financial and educational institutions, or inequalities in wealth distribution. Racial justice is defined here as the belief that all racial and ethnic groups should be treated equally and that society should provide equal opportunities to all (SRJ). These concepts are discussed across teacher education programs and are encouraged in teaching practice, so we were interested in seeing how they were enacted in STEM classrooms and how teacher research experience may have impacted this enactment. A biology and chemistry teacher, Teacher LP, in their interview mentions a lesson where they navigated representation issues in STEM with their students, particularly of women and people of color which we coded as SRJ.

I had my freshman students do a research poster about different scientists of color or female scientists, you know. Not just your typical old white male scientists. I talked to them a lot and said you're going to see a lot of that in your textbooks but that's not what every scientist looks like. It was really great because we added a lot of discussions on you know why, when you look at the history books and the science books, you see a lot of you know, old white men. Were there no other groups involved in science back then? And really talking them through, you know, there's definitely barriers for certain groups of people that might not exist for others.

The Coding Frequency data indicates that most of the teachers were able to describe at least one instance where they tried to incorporate educational equity or awareness of social and racial issues (represented by the EQF and SRJ codes respectively). An example of this can be found in Teacher A18's lesson on physical science explanations for human skin color and its relevance to race. This general response holds true with our teachers regardless of grade level or subject. In fact, the

teacher's responses to the interview questions relating to these constructs were among the most detailed in the entire data set.

Well, one of the main things in terms of equity that I got from [my Undergraduate Teaching Credential Program] is CRP, or culturally relevant pedagogy and just trying to incorporate more aspects of students' identity in the curriculum. This part proves difficult with physics because it can be, it's not as able to draw from like other social issues, like biology can, or like how a lot of social issues can be directly addressed by biology. But one thing that I did that was also intended to give inquiry is I tried to get across that melanin, the pigment that gives our skin a color, has physical properties and that's why we have it. For example, I wanted them to discover some of its reflective properties. Some of its UV reflective properties by testing different things that are meant to reflect UV light. They were able to discover that themselves. None of this was direct instruction that I gave them.

Teacher A described an instance of educational equity during remote instruction for their students and making sure that students could engage in class within their means and circumstances.

I felt really motivated to continue to teach like lab classes during Zoom because people were missing out on that and I felt like that was enrichment that was really important. I also thought a lot about what kinds of materials I realistically ask my students to procure and what kind of burden I was putting on students to do that. And so I, in thinking about that one, I gave them a heads up a month in advance that they would need this. I checked in two weeks and was okay, like, you know, if you're still worried about getting any of these things, let's talk about it. I talked to some parents where the expectation was not like I need you to procure this, but rather, is this something that's doable or not? If it's not doable, we'll work around it.

Overall, our data provide evidence that there is a wide range of interpretations and implementations of scientific inquiry used in the K-12 STEM classroom from pre-service teachers, even those who have studied and trained under the same teacher education program.

Theme 3: Teachers Use NGSS Science & Engineering Practices with Student-Centered Investigations

We coded for the 8 Scientific & Engineering Practices (SEPs) from the NGSS, because they relate to specific practices and activities that undergraduates master in UREs and that K-12 students are expected to learn in the STEM classroom. In addition, we coded for “iteration and evaluation” of experimental design rationale and limitations (SRP-DCR and SRP-DCL). We also created a code that represents teaching practices that connect scientific discussions to societally relevant applications, and codes that represent connections between scientific concepts, practices, or student teamwork (SC-C, T, and P). Figure 1.3 depicts the Coding Frequency of codes in the *Scientific Practices* category across all of the initial 24 teacher transcripts. See the *Appendices* for a full description of each code in this category.

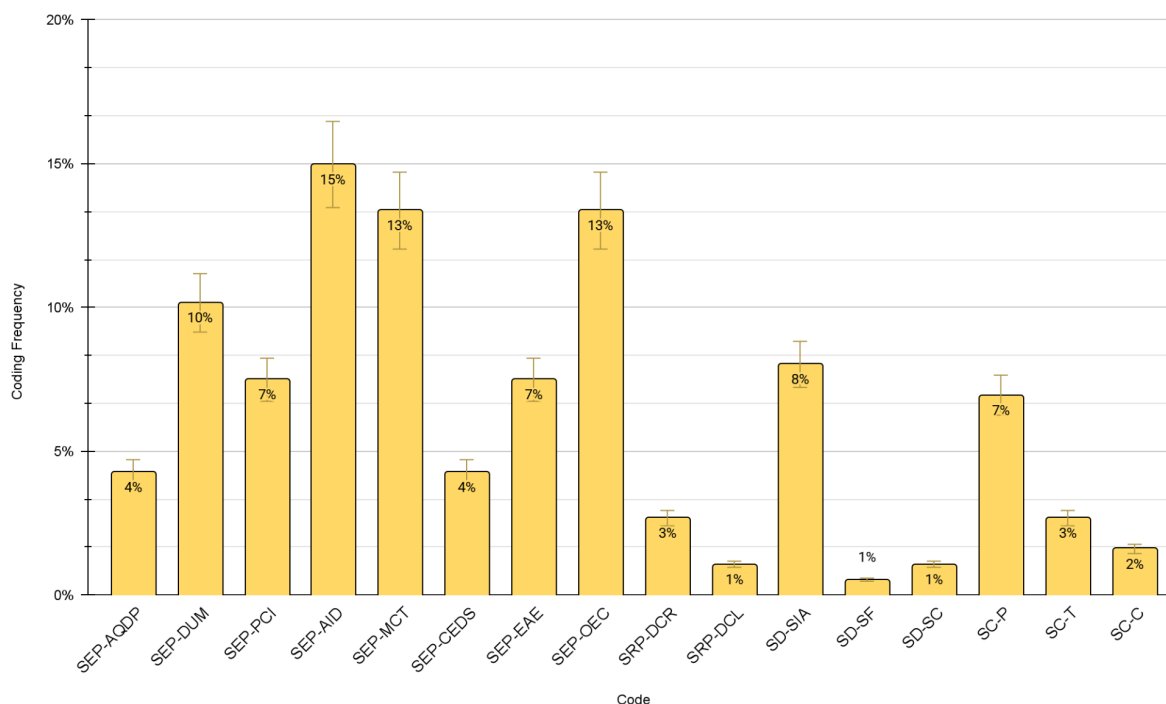


Figure 1.3. Coding Frequency (number of times a code was used relative to the rest of its coding category) for Scientific Practice codes (n = 24). Codes include: Science & Engineering Practice - Asking Questions and Defining Problems (SEP-AQDP); Science & Engineering Practice - Developing and Using Model (SEP-DUM); Science & Engineering Practice - Planning and Carrying Out Investigations (SEP-PCI); Science & Engineering Practice - Analyzing and Interpreting Data (SEP-AID); Science & Engineering Practice - Mathematical & Computational Thinking (SEP-MCT); Science & Engineering Practice - Constructing Explanations and Designing Solutions (SEP-CEDS); Science & Engineering Practice - Engaging in Argument from Evidence (SEP-EAE); Science & Engineering Practice - Obtaining, Evaluating, and Communicating Scientific Information (SEP-OEC); Scientific Refinement Practice - Design Choice Limitations (SRP-DCL); Scientific Refinement Practice - Design Choice Rationale (SRP-DCL); Scientific Discussion - Societal Impact/Application (SD-SIA); Scientific Discussion - Scientific Fulfillment (SD-SF); Scientific Discussion - Scientific Context (SD-SC); Scientific Connections - Practices (SC-P); Scientific Connections - Teamwork (SC-T); Scientific Connections - Concepts (SC-C).

We found that there was a frequent and effective integration of a variety of scientific practices in tandem with the lesson plans and teaching practices described or associated scientific concepts that were the focus of an inquiry lesson. Below, Teacher JM and RC reflect on the various scientific and engineering practices in a typical lesson they facilitated involving scientific inquiry.

Teacher JM:

We always have some sort of investigation planning and carrying out said investigation. Then, they need to analyze and interpret that data. And then, I eventually asked students to use that data to create a claim with evidence and reasoning so that's engaging in argument from evidence. Yeah, it's usually related to the [grounding] phenomenon.

Teacher RC:

I think the models and investigations would sometimes be hand in hand, where, for example, they had to model a parachute before they started to design it.

Each of the 8 scientific and engineering practice codes (SEP-AQDP, SEP-DUM, SEP-PCI, SEP-AID, SEP-MCT, SEP-CEDS, SEP-EAE, and SEP-OEC) were well represented in the data. However, two were used less frequently than the others (SEP-AQDP, SEP-CEDS), perhaps not surprising as formulating research questions or constructing explanations about what happens during an investigation is sometimes

considered more age appropriate for advanced K-12 students or higher education. The high level of diversity in grade levels and STEM subjects in our sample could have contributed to this variety. Interestingly, we saw a high representation of the scientific connections practice (SC-P) and the Scientific Discussion - Societal Impact/Application (SD-SIA) codes, which focus on direct connections between different scientific and engineering practices and contemporary issues that are relevant to their lives or discussions in class. Teacher L18, a teacher in both physics and biology, was able to recollect a clear connection (SC-P) between “Developing and Using Models” (SEP-DUM) and (SEP-EAE) “Engaging in Argument from Evidence” practices in her lessons.

I think that, just like the two that we've really been focusing on, like creating models, using models, and then arguing to support a claim or create a claim. I feel like there's been a lot more connection between those because that was a priority we were focusing on this year, being able to find evidence from multiple sources and use that for arguments. So I think being able to use visuals as evidence has been showing up a lot.

Teacher JM shares an example of students discussing a Societal Impact/Application (SD-SIA) and “Developing and Using Models” (SEP-DUM) while making predictions on a scientific phenomenon such as climate change.

For example, there's this greenhouse gases simulation and it has variables that you could change how much greenhouse gases were in the environment and then you could monitor how it affects the temperature. How would it affect the heat coming in and how would it affect the heat coming out of the atmosphere and I guess like using that model students had to like basically make predictions about what's the atmosphere is going to be like or what's the world going to be like if we have this much greenhouse gases this and so on.

Codes relating to scientific iteration are found with low frequency (SRP-DCR and SRP-DCL). Nonetheless, some teachers, such as Teacher RC, demonstrated active efforts to integrate the two codes, which provides us with additional examples of students engaging in scientific inquiry. These two codes were used when students were reported to reflect or reiterate on design choices or limitations in science experiments.

So in the first semester we built boats and the boats had some iteration and modeling. So we started off small with little foil boats that took like a minute to build where you just kind of like shape a piece of foil, throw it on some water, and see how many pennies are going to hold. From there, we did straw boats. They were built out of straw with hot glue guns and then we segued into PVC boats that are big enough for students to get in. So the goal is to get at least two students to get in this thing and actually float..... And that's how they were testing their boats and it worked fine. It was great. But the reason I'm saying that is because it focused a lot on iteration because if the boat fails, then they actually were able to test it and then iterate on it, and like figure out, “Okay, why did it fail?” Let's go back to the drawing board and figure out what happened (SRP-DCL).

So they can test whatever they want and however they want. And the whole point is for them to practice experimental design and isolate variables, so that was a big thing that we emphasize, like what's an independent variable, what's a dependent variable, and what's a controlled variable. How do you design your experiment where it's like a safe, sound experimental design that isolates one single variable that you're testing (SRP-DCR).

Overall, there are many instances of teachers being able to reflect on and engage students with a variety of teaching practices, including the 8 NGSS Scientific and Engineering Practices, in ways that complement specific STEM course content in the classroom.

Theme 4: Teachers Develop Practices Over Time that Emphasize Scientific Inquiry Based on 2nd Interviews

We interviewed 4 teachers (A, C, J, and CI) in our study for a second time to explore how teachers who engaged in an undergraduate experience further developed their teaching practices for scientific inquiry, if at all. Second interviews took place a few years after their first interview, remained semi-structured in nature and used the same interview protocol. We also coded this subset of interviews, but in these cases, we focused on identifying new examples of scientific inquiry in the classroom, identifying changes in the implementation of scientific inquiry, and identifying the consistency with which teachers describe their UREs and how those experiences shaped their ongoing K-12 STEM teaching.

First, each of the four teachers in this subset indicated that they were still active teachers within middle or high school STEM. Two of the four teachers were teaching slightly different subjects and/or grade levels compared to what they were teaching in their first interview. We identified additional or novel examples of scientific inquiry from these teacher interviews. Teacher CI, for instance, talks about their continuing increase in student-centered scientific inquiry in general.

[I put] a lot more focus on the students doing the work. And that's not saying that I don't do anything, but there's definitely more of them trying to figure things out. And I just have to make sure I take the time to plan and scaffold things so that they get the right information at the right time.

In their second interview, Teacher A emphasizes and better articulates how helpful it is to be able to increasingly navigate academic literature and pull information from it that can be used in lesson planning.

One of the things that I didn't know how to do before research, and I did know how to do after, was really read the literature and pull out key pieces of information from it. Super useful skill generally in life. For my teaching, I think the way that it showed up was mostly just in my lesson planning. Honestly, I had a hard time actually getting students to read multiple sources and put together a much smaller picture from many sources that have very different agendas. It's a challenging thing to do... but it was super important when I was thinking about how to design inquiry-based lessons for my students. Research was something that was really helpful for pulling together ideas from multiple sources to make something that I felt was like a coherent and relatively polished whole lesson.

Different inquiry impression codes (II-SC, II-TG, II-AS) came up for the first time for each of the 4 teachers in the second interviews compared to their first interviews, indicating that their general perspectives and implementation approach of scientific inquiry had changed over time. In Teacher A, CI, and C's case, we noted a change from teacher-guided to student-centered inquiry in their classrooms. All 4 teachers were also able to demonstrate continued usage of inquiry teaching practices (TP-Dom C, P, E, and S) in their most recent lesson plans.

We were able to utilize more of our coding scheme for the second interviews than before to examine research impacts on teaching. We noted that teachers, despite referring to the same research experience as in their 1st interviews, were able to describe their UREs at a much deeper and at a more appreciative level. All of the teachers were more clearly able to articulate specific ways that they connected the research to their teachings. For example, Teacher J, a computer science teacher,

emphasized the iterative process that is fundamental to research (TP-DomE) and Teacher C highlighted how undergraduate research influenced their perspective on scientific inquiry (II-SC), neither of which came up in the first interview.

Teacher J:

So I think it's made me more patient in teaching or designing experiments after we submitted the paper. We've got the feedback and we need to revise it and revise it. It makes me understand, like doing experiments is not a one-cycle thing, it is multiple, multiple cycles. I emphasized this a lot in my current teaching and it has made quite an impact on my current teaching.

Teacher C:

I think I particularly like getting paired with the mentor teacher who I was with [during research].I think the way that she approached her teaching practices were really influential in what I would want to do when I became a teacher. She was just really focused on making sure that her students, if they have had a misconception, that they felt safe to voice their misconceptions or voice their concerns. And then to be able to address them and not just answer their questions, but to pose a question for the student to figure out themselves rather than use a Socratic method kind of style. Just rephrasing the question or asking the underlying question to get the student on the right track. I think I've sort of adopted that teaching practice in my class. [For example], the answer is that electrons are negative. How are the electrons interacting with each other? How does that influence the phenomenon that we're trying to talk about? So it's not necessarily me having to... I'm not just providing a fact. [I'm] having them construct explanations themselves [in class].

Our findings here suggest that perspectives and implementation strategies for engaging students in scientific inquiry, starting from research experiences, continue to develop and improve throughout the teacher's career.

Discussion

Teachers Ground their Science Lessons in Phenomena of Interest

An important outcome of our study was the contextualization and visualization of specific connections between UREs and STEM teaching practices. Our findings are consistent with our prior work about the evaluation of student learning in UREs (Coté, 2024; Helix et al., 2022;) and several theoretical frameworks relevant to STEM education that lie at the foundation of our work (see *Theoretical and Other Frameworks* section). Our first finding was that teachers in our study indicated that they became more familiar with the general “structure” of what scientific research and inquiry should “look like” through participation in research. For many pre-service teachers, UREs are the first chance they get to engage in authentic scientific inquiry. The greater insight into what scientific research entails assisted pre-service teachers in building a more comprehensive intuition for how to teach science, consistent with a previous study (Pop, Dixon, & Grove, 2010) in which active teachers who engaged with a 6-week summer research experience walked away from it with a change in “*thinking on how to teach science*”.

Alongside helping pre-service teachers gain an understanding of scientific research, our study shows that research participation also shaped instruction substantively, including their contextualization of lessons. We found that when teaching science to their middle and/or high school students, teachers ground the phenomenon of interest as a contemporary problem that requires solving. Some teachers in the study reported that doing research “helped them see” what are common research objectives and tasks that scientists “can do” to address relevant problems. Other teachers, when

prompted to share and describe their UREs, emphasized new pieces of STEM content knowledge that they had learned. This is similar to what has already been reported in Brown & Melear, 2007; however, teachers featured in our study described that undergraduate research helped develop and/or reinforce STEM content knowledge for their respective disciplines, which was critical for their teaching. Holistically, insights from how science is actually carried out “in action” and how STEM content knowledge is applied in research settings assisted the teachers in crafting the scope of lessons that were grounded around a phenomenon of interest in a science area familiar to them.

Undergraduate researchers generally are provided with background information and research articles from their research mentors as they start their projects, so that they can become familiar with the research context. This research practice has also been translated to these teachers' classroom practices in the form of using academic literature to help introduce new concepts in class, and to contextualize lessons in terms of ongoing scientific research. Another interesting note here is that despite pre-service teachers being required to communicate and publicly present their research findings at the end of the research experience, no teacher in our sample mentioned how their past research project presentations supported learning how to scientifically communicate in a URE. Nonetheless, there were numerous instances of teachers placing a large emphasis on scientific communication in their own class.

UREs Influence Implementation and Perception of Scientific Inquiry

Our study is the first to apply the four domains from the Cognitive Dimension of Inquiry to the context of K-12 STEM Education. We defined scientific inquiry as student engagement in methodological scientific investigations, such as those identified by the Next Generation Science Standards “Scientific and Engineering Practices.” This inquiry, we argue, can be guided by instructor teaching practices that elicit the four domains of the Cognitive Dimension of Inquiry. The domains of inquiry focus on content, procedures, epistemology, and social practices in the research process (See *Theoretical and Other Frameworks* section and *Methods* section). This framing aligns with the BURET research team's past work in evaluating student learning in STEM UREs (Coté et al., 2025; Coté et al., 2026; Coté, 2024; Helix et al., 2022).

From our coding analysis, we found that actions required to engage with (and are commonly associated with) the Cognitive Dimension of Inquiry in a research context to be adaptable for K-12 STEM Education. For example, a teaching practice in the conceptual domain (TP-DomC) involves K-12 students learning an important scientific concept or theory which helps students build a formative content knowledge foundation that can be integrated into a science lesson. On the other hand, a teaching practice in the social domain (TP-DomS) involves teachers having students share and discuss with each other scientific content and/or practices. Observing a predominance of both domains in our results suggest that the interviewed teachers are setting up productive learning environments where students can engage effectively amongst themselves in scientific inquiry. We found that teachers were able to highlight and describe in detail numerous instances of scientific collaborations, discussions, and presentations among their students.

The epistemological domain of inquiry (TP-DomE) is seen less frequently in our codes, which aligns with past results from Coté (2024), as graduate student mentors focus less on these practices than others in the Cognitive Dimensions of Inquiry. This is not surprising for K-12, since for a pre-service or active teacher with research experience to actively engage students with scientific investigations that pull from the epistemological domain of inquiry, (such as the generation of scientific knowledge, interpretation of data, validating hypotheses, and evaluating experimental design) it requires a significant time investment in STEM research which is not always possible.

It is apparent from our study that there are challenges (IOI-Ch) for the advancement of scientific inquiry in the classroom. The challenges we saw included curriculum restrictions, more pressing student needs, minimal collaboration between teaching programs and research labs, and not having enough institutional resources when it comes to putting together scientific lessons that can give students a chance to engage with scientific inquiry across the four domains. It is difficult to create consistent structures, connections to teaching practices, and homogeneity in research experiences for teachers to develop shared approaches to scientific inquiry (Blockus et al., 1997; Crowe & Brakke, 2008; Kardash, 2000). Not to mention that research mentors might consider there to be a fundamental difference between learning science in a classroom versus doing science in a research lab. This inconsistency in undergraduates research experiences can also be a positive. UREs will create unique and varying implementations among teachers of content knowledge, scientific practices, and science mentoring in K-12 STEM classrooms for students. This can lead to opportunities for increased specialization and diversity of thought as K-12 science teachers continue to develop their teaching practices throughout their career as we have observed in through second interviews several years later in our study of a subset of teachers.

Codes such as II-SC indicate a perception and/or implementation of scientific inquiry that represent student-centered, independent investigations. Codes such as II-TG represent a practical, hands-on, teacher-led perception and/or implementation of scientific inquiry. The National Research Council (2013) has supported an implementation of inquiry similar to II-SC. Indeed, we found that the student-centered impression of inquiry, II-SC, was featured heavily in our data as 16 of 24 teachers (about two-thirds) described or implemented scientific inquiry in this manner in their lesson plans. This result aligns well with how they would experience research as a pre-service teacher. Many teachers mentioned that they had more of an opportunity to work independently on a research project as an undergraduate, with minimal supervision/guidance from their mentors. This carried over into how scientific investigations would be organized in their classrooms and teachers would structure their level of involvement to best help students engage in scientific inquiry.

Second interviews provided evidence that teachers develop their teaching practices toward a more comprehensive view of scientific inquiry. We noted that with a few extra years of teaching experience, this subgroup of teachers in our sample were able to design lesson plans that had more roots in what they experienced during research as they were able to further reflect and contextualize what they considered to be the most important takeaways from their undergraduate projects. These lesson plans

had also engaged students more thoroughly with the NGSS Scientific & Engineering practices.

The National Research Council (2013) recommends that K-12 students are to engage with all aspects and practices of a typical scientific research investigation. Teachers in this study, after participating in UREs, have shown that they can implement various scientific practices in the classroom that are suitable for novice scientists such as data collection, developing and using models, and obtaining/evaluating scientific information. The scientific practices that were reported by teachers the most often were, *SEP-Analyzing and Interpreting Data* (SEP-AID) & *SEP-Mathematical and Computational Thinking* (SEP-MCT). These scientific practices have clear analogues to what teachers emphasized when recounting their past research projects and their research contributions in the interviews, and indeed, the goals of the teacher education program. Our work builds upon Melear et al. 's (2000) findings that pre-service teachers learned some of these same scientific practices while doing research in a dedicated course at their institution.

Connections Between UREs & STEM Teaching

Our data and subsequent qualitative analysis suggest that most teachers in our sample did not recollect what they learned from the research projects of their UREs in great, holistic detail. Teachers' descriptions of their UREs often focused on the “what” rather than the “how” and the “why.” For example, teachers in our study frequently describe content knowledge required or the application of the research as standout elements from doing research as a pre-service teacher, but less often reflect on their own personal/technical growth with research, unique scientific insights provided from their research, and their relationships with their research mentor/lab instructors. It is plausible that their responses were influenced by trying to connect K-12 STEM teaching “in the moment” as connections between research and teaching since that aligns with one of our research study questions.

The lack of detail when recounting their UREs by our research participants differs from other studies in the literature. For example, Silverstein et al. (2009) reported positive effects of having active in-service teachers engage in research as more experienced classroom teachers were reported to have successfully implemented additional lab activities, lab techniques, and revised STEM content. All of which we have also seen for the pre-service teachers that we featured in this study. Silverstein et al. (2009) also quantified the resulting outcomes in terms of post surveys, examinations, and researcher observations. We have opted for a more descriptive and qualitative approach that allows for more diversity in analysis across grade levels and disciplines for pre-service teachers engaging in UREs as part of their teaching credential programs. Raphael et al. (1999) reported that their participants described their UREs in detail and what they felt they would take away from it right after its completion in the form of an exit interview and a written reflection. Meanwhile, the participants in our study were asked to recollect their UREs with a 2-4 year gap between it and their interview, which enabled them to identify additional specific connections to their current teaching.

Recommendations & Implications for Enhancing UREs for Pre-Service Teachers

Research is a lengthy, methodological process with many social, conceptual, procedural, and epistemological facets. Oftentimes the different steps of the research experience are connected in abstract ways which complicates approaches that teachers could take to engage students in scientific inquiry through scientific investigations similar to research. To help active teachers think about research and to help develop their students' notion of scientific inquiry in more concrete and specific ways, it could be beneficial to engage pre-service teachers with explicit examples for translation of science investigations into the classroom when they participate in UREs. Because the teachers in this study were simultaneously enrolled in a CURE course and engaged in an authentic research project, guided by faculty research mentors and their graduate students, there was an explicit structure that likely enabled translation into the classroom. Additionally, teaching credential programs (or similar teacher preparation programs) that revolve around having pre-service teachers engage in UREs, research projects could encourage research mentors to connect and tie-in the concept of scientific inquiry as it is taught in the K-12 curriculum to what the student is doing in the project wherever possible. Research mentors should also provide projects that can be completed within the time available and their mentoring approach should be synergistic with the type of teacher the student is aspiring to be. An ideal URE for pre-service teachers cultivates an environment where they are encouraged to grow professionally and personally as instructors in their STEM disciplines, in addition to their growth as a researcher. It could also be helpful for pre-service teachers to have an explicit focus on academic and professional pathways to doing science as a career. In addition, normalizing failure, addressing imposter syndrome, and providing guidance on how to navigate the hidden curriculum could also be helpful for occasions in the classroom where the teacher can pass this knowledge along to their students.

Indeed, more work should be done to have UREs that are more specifically helpful for students who anticipate becoming a K-12 STEM teacher in the future. We propose that more dedicated support for these students in research and further integration with their teaching credentialing programs would benefit all parties involved and have the downstream effect of adequately training the next group of undergraduate researchers as a result of effective K-12 STEM teaching. However, we acknowledge that this level of integration and focus in UREs in teaching credential programs would require considerable resources, collaborations, and time investment which may not be feasible for every context. Regardless, we remain optimistic that as more students, including pre-service teachers, engage in research that more aspiring undergraduate students will be better prepared to succeed as teachers and as scientists. Having pre-service teachers engage in research is the key to bridging the divide between “learning science” and “doing science” for K-12 STEM students.

Conclusions and Future Work

Overall, our work features a qualitative analysis of the impacts of UREs on the teaching practices and implementation of scientific inquiry of pre-service teachers in STEM throughout their careers. For a majority of the teachers, their teaching practices

were affected by research by enhancing the contextualization of lessons to scientific problems of interest and enhancing the lesson designs themselves with more involved demonstrations of what science is actually like and more integrated utilization of the NGSS Scientific & Engineering Practices. Research helped teachers get more creative with how they can get engaged with scientific inquiry with lesson plans that acted akin to independent student-centered scientific investigations. As some teachers continued to refine their instruction with additional years of experience, they also continued to evolve their perspective and implementation of scientific inquiry in their science classrooms.

We would also like to highlight the fundamental difference in learning science in the classroom versus in the research lab. One is designed around developing the established fundamental building blocks of scientific knowledge within a person while the other is more about generating new scientific knowledge for a larger application or body of insight. Theoretical frameworks such as the Next Generation Science Standards attempt to bridge the gap here via Scientific Practices, Core Disciplinary Ideas, and Cross-Cutting Concepts, but these frameworks still require significant and conscious actions by teachers to be effective. We assert that teaching credential programs that have UREs as a core component should more clearly connect research skills and knowledge to supporting students in navigating scientific investigations, integrating into academia, and developing critical thinking skills for their development as future scientists.

We have reaffirmed that implementation of scientific inquiry via NGSS is fruitful, but still challenging in a practical, logistical, and conceptual sense. Some aspects of NGSS don't take into account the unfortunate limitations that teachers may face in the K-12 classroom (teaching standards, rigid curriculum, lack of institutional support, student learning difficulties, lack of time, etc) that could make it difficult for scientific inquiry to be implemented on a wide scale. It is clear to us that, in general and in research, more coordination is needed between frameworks such as *A Framework for K-12 Science Education* and the teaching credential programs that are in the best position to adapt said framework so that they can lead the way on prioritizing scientific inquiry in K-12 STEM classes through teaching practices that are grounded in the domains that comprise the Cognitive Dimension of Inquiry. In the future, we plan to supplement and support our findings from the interviews with direct classroom observation and by studying the student throughout their teacher training to better understand URE impacts on K-12 STEM teaching.

Chapter 1 Contributions

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Chapter 2: BURET-TAMUS Instrument: Surveying the Extent and Integration of Undergraduate Teaching and Mentoring Practices across Commonly Experienced Factors in Research Experiences (Project 2)

Introduction and Motivation

College students acquire many experiences throughout their degree programs that influence many aspects of their professional and personal development. In the context of Science, Technology, Engineering, or Mathematics (STEM) programs, students undergo rigorous scientific coursework which develops their critical thinking and problem-solving abilities, increases their STEM content knowledge, expands their prowess to evaluate and communicate scientific results and data, and provides them with an opportunity to acquire new sets of skills (Sadler et al., 2010). Students can also opt to participate in undergraduate research experiences (UREs) to experience more practical scientific work than they would during their courses. Student participation in UREs can have several positive outcomes. These include, but are not limited to, increased student learning, student integration with the academic scientific community, possibilities to network with researchers for professional and academic opportunities, personal growth of students' scientific identities and confidence, increased STEM retention and participation in STEM careers, and development of students' sense of belonging in STEM (Adedokun et al., 2012). These positive outcomes have been reported and qualitatively corroborated through numerous studies in the literature (Auchincloss et al., 2014; Fechheimer, Webber, & Kleiber, 2011; Hernandez et al., 2013; Krim et al., 2019; Linn et al., 2015; Russell et al., 2007; Russell, 2008).

Research experiences, and the positive outcomes linked to them, are enhanced by the teaching and mentoring that students are experiencing within them (Aikens et al., 2016; Amaya et al., 2018; Atkins et al., 2020; Haeger & Fresquez, 2016; Malachowski, 1996; Walkington et al., 2019). In a typical STEM URE, students work with a mentor, such as a faculty member, a lab scientist, or a graduate student. Mentors are expected to guide mentees throughout the research project and provide the mentees with the support and environment needed for them to thrive as scientific researchers (Boysen et al., 2020; Harris et al., 2015; Horowitz & Christopher, 2013; Pfund et al., 2016; Robnett et al., 2018). In addition, mentors teach the mentees to appropriately understand the content of their research project, learn valuable skills needed to perform scientific work, and to develop the ability to use these knowledge and skill sets to make insightful discoveries within their disciplines. Mentees should be expected to communicate with their mentors about their needs and meet the work expectations set in place by the mentor. The two parties help each other to create a mentoring relationship that is mutually beneficial for each other's development into practicing scientists.

In practice, a mutually beneficial mentoring relationship with effective instruction is difficult to achieve and model. Most STEM URE programs last for a short amount of time, which incentivizes mentees to focus more on academic learning goals or achieving research results than on long-term development as scientists or the

mentoring relationship between students and mentors (Taraban & Logue, 2012). The structure of typical URE programs also contribute to these issues because the mentor role is often placed on individuals who lack training or lack institutional resources (Amundsen & McAlpine, 2009; Johnson et al., 2015; Ruben, 2020; Titus & Ballou, 2013). Thus, certain key aspects of mentoring are often absent or employed ineffectively in UREs.

Effective teaching throughout the research experience can also be critical towards fostering the mentee's development as a scientist. Some studies have provided evidence of the benefits of effective teaching on various mentoring outcomes in UREs (Nolan et al., 2020; Sabatini, 1997; Wrighting et al., 2019). As with mentorship, however, mentors may have limited teaching experience or may not yet be experienced enough researchers to effectively train other students on the research project. In addition, UREs are expected to lack homogeneity in terms of what the experience is like for the student due to differences in research mentor's availability/style, lab objectives, resources, expectations across disciplines, the discipline itself, and the mentee's starting goals, experiences, and self-efficacy (Blockus et al., 1997; Crowe & Brakke, 2008; Kardash, 2000). These limitations with mentors and URE programs compound with many other factors that affect students to influence the undergraduate teaching and mentoring that occur in UREs.

To better understand the extent to which factors that students experience in research promote or inhibit the student outcomes in UREs, there is a need to develop an instrument to measure and contextualize how factors are shaping the student research experience. We propose that a stronger understanding of the general student research experience via instrument measurement will also help to identify factors that can be controlled to help institutions design UREs to be more consistently beneficial for all students, regardless of background or circumstances. Such an instrument would be helpful to the STEM educational research community as well as there is little literature that evaluates teaching and mentoring practices that students are exposed to in UREs (Crisp & Cruz, 2009; Gershenfeld, 2014; Jacobi, 1991; Linn et al., 2015; Pfund, 2016), while also drawing connections with other factors of research that students experience. More studies into this area could also help with training research mentors with practices that have been proven to be effective and promoting factors that have been shown to complement student development. Measurement of multiple factors in a single instrument also provides the opportunity to analyze how the factors affect each other and thus, impact how students learn while doing research.

We report here our study to directly measure and analyze student experiences in UREs with a new instrument: **The BURET-Teaching & Mentoring in UREs Survey (BURET-TAMUS)**. More specifically, this survey instrument quantitatively and qualitatively measures the factors common in UREs that can influence both the teaching and mentoring that mentee's experience conducting research and see what insight and distinctions can be garnered from such a measurement. The pilot study aims to address the following question: *How do mentoring and teaching practices that undergraduate students experience influence certain factors and outcomes of the undergraduate research experience?*

Theoretical and Other Frameworks

Construct Modeling

In this research context, instruments can be considered to be techniques or processes through which one measures a human attribute. The act of “measuring” with an instrument is an intentionally designed and methodological process to obtain information about a person’s attribute of interest as some sort of output or value (Wilson, 2023). Measurements should ideally work to establish trustworthiness of the output by accounting for or explaining random and systemic variations in the measurements. In the social sciences, addressing random variations is known as establishing the reliability of a measurement while addressing systemic variations is known as establishing the validity of a measurement (Mari, Wilson, & Maul, 2023).

The human attribute that is the subject of an instrument’s measurement can consist of a person’s specific ability, latent trait, behavior, or characteristic attitudes (Wilson, 2023). For the purposes of this work, we assume that an instrument is measuring one attribute at a time for each person. An instrument is capable of measuring multiple different attributes over the course of a measurement, but in these cases the instrument in question can be considered to be composed of several “smaller” instruments that are measuring a specific attribute of interest. Henceforth, we refer to individuals that are being measured as “respondents” or “participants” or “students.”

In this chapter, we utilized the approach from Wilson (2023) known as *Construct Modeling* for our measurements of various factors and attributes that students can experience during UREs. *Construct Modeling* is a constructive approach for measurement that builds upon the National Research Council’s (NRC) (2001) approach for educational assessment in the social sciences. The NRC outlines that every assessment contains three components. The first component, *cognition*, states that every assessment is grounded in a theory or framework about how people learn or what they already know. The second component is *observation* and states that every assessment embodies some assumptions about which types of observations or demonstrations are most likely able to elicit evidence of knowledge from people. Lastly, the third component, which is *interpretation*, states that every assessment contains assumptions for how to best interpret the evidence about what people know.

In a similar fashion, *Construct Modeling*, emphasizes evidence based design for measurements (Mislevy et al., 2003). The difference in the two approaches comes in the form of converting the three components from the NRC approach into a cyclical and iterative sequence of four “building blocks” for assessment (or instrument) development (Wilson, 2023). As an aside, *Construct Modeling* refers to the attribute being measured by an instrument as a “construct” and that term shall also be used for the remainder for this chapter. The *cognition* component is converted into the “Construct Map.” The Construct Map is a defined, unidimensional, descriptive, scale of change for the construct that is being measured by the instrument. It is also akin to a “theoretical structure” of the construct (Wilson, 2023). For example, if we consider “motivation” as our construct of interest, our construct map would be defined as ranging from “high” to “low” so any respondents that are measured would be somewhere within that range. *Construct Modeling* makes a few assumptions when it comes to the Construct Map.

First, we assume that the construct is indeed unidimensional and that someone's "motivation" for instance, does not lie outside the defined range. Second, we assume that there exist consecutive and distinguishable qualitative points between the extremes of the Construct Map (Wilson, 2023). These qualitative points are known as the "waypoints" and they help to visualize the Construct Map as "a roadmap of change." Waypoints must include a qualitative description that distinguishes it from the other waypoints which helps to interpret measurement outputs and enables comparisons between respondents. The final assumption is that each respondent's construct measurement can also be located as being somewhere between at least two waypoints (Wilson, 2023). Waypoints do not necessarily have to be equally "spaced apart" in a Construct Map.

The *observation* component is converted into the "Items Design." The Items Design is the "plan" through which the measurer can manifest the construct from the Construct Map through a real-world scenario or set of tools that the respondents can "respond to" to indicate via the instrument their position on the Construct Map (Wilson, 2023). This part of an instrument is often referred to as just the "items" in *Construct Modeling* and the items can take on many different forms depending on the construct, the measurer's intent, or accessibility accommodations for the respondents. Examples of items are multiple choice questions on a survey instrument or open-ended prompts where respondents can describe their answer in their own words. The Items Design does not necessarily have to be formulated after the Construct Map. In fact, it may be useful to create Construct Maps after coming to a decision on what items will be included in the instrument. The Items Design can also provide insight during instrument development on how to iterate and refine the Construct Map and vice-versa. Either way, the Items Design makes the assumption that the respondent is aware that they are being measured through the instrument and, in spite of that, only the construct itself is "causing" the respondent to respond a certain way to an item. In actuality, the relationship between the Construct Map, the responses elicited of a construct, and the influence that interacting with the instrument has on said responses is a bit more complicated. Statistical models will be explored later in this section that help to increase the understanding of this relationship.

The *interpretation* component is converted into two building blocks of *Construct Modeling*. One of these is the "Outcome Space." The Outcome Space is the process through which aspects of item responses will be categorized and scored to obtain some sort of inference (Wilson, 2023). As with items, the Outcome Space can take many different forms and its final product is often decided by the measurer. A measurer can also use the Outcome Space to inform decisions on how to iterate or refine the Construct Map and Items Design.

The other building block is the "Wright Map." A Wright Map serves to connect scores from item responses from each respondent onto a location on the Construct Map. To achieve this, a Wright Map must have two parts. The first part is to decide on a statistical model. The statistical model translates the scored item responses onto a metric which is the second part of the Wright Map. The metric is supposed to represent the Construct Map and individuals can be sorted into different categories along the metric based on where their measured construct would be located as determined from their scored item responses. These different categories can be chosen based on

waypoints or by specific items. Wright Maps are significant towards the interpretation of a *Construct Modeling* measurement because it enables the measurer to compare empirical results between individual or groups of respondents by placing them all on the same qualitative “metric” based on the Construct Map waypoints.

The statistical model that is most commonly used in *Construct Modeling* is the Rasch Model which is described in the following sub-section. Its relative simplicity and ability to obtain several statistical parameters that can aid in measurement interpretation makes it ideal for simpler constructs, or at the very least, constructs that follow the assumptions that were made earlier in this sub-section. However, the Rasch Model can also explain and account for some of the random and systemic variations that occur in repeated measurements or across individuals that have different experiences with responding to the instrument items. Thus, the Rasch Model helps to establish instrument reliability and validity which is important when communicating the interpretation of results in the social sciences.

The Rasch Model

Individuals have had different perspectives for how to connect the construct being measured to the item responses obtained from an instrument. Most people fall into two categories on this matter. The first is Guttman Scaling which is an item-focused approach that emphasizes the meaningfulness of the results obtained from the instrument by matching items to the construct map (Wilson, 2023). The Guttman Scaling approach provides information about a measurement’s validity, but is limited by the types of items that are compatible with the approach (Guttman, 1944; Guttman, 1950). For instance, Guttman provides numerous examples of scenarios in his work where item responses are categorized based on a numerical score of the responses, which may not work for items that are more open-ended and allow for respondents to be more descriptive. Guttman Scaling, by the interplay between Items Design and Construct Maps, limits the type of constructs that can be measured. Constructs that can be easily scored such as ones that focus on individual performance in a task will be more compatible with Guttman Scaling than those that are more abstract or focused on measuring individual development (Guttman, 1944; Guttman, 1950; Wilson, 2023).

On the other hand, utilizing Classical Test Theory (CTT) offers an alternative by matching item scores to the construct map (Wilson, 2023). In CTT, the statistical nature of the item scores and places emphasis on the consistency of the measurement, i.e., its reliability. The general idea is that a respondent’s score, the observed score by the instrument, is the sum of the respondent’s “true amount of the construct” (their true score) and an “error” value. Errors should not be considered to be mistakes made by the instrument or the respondent, but rather random “noise” that influences the measurement (Finch & French, 2019; Nunally & Bernstein, 1994). Errors can be composed of many independent entities that are separate from the true score. Under this idea, statistical modeling can parameterize the error and allow the measurement to more easily and accurately map onto the Construct Map. This enables more types of constructs and responses to be measured and interpreted as the measurer has relative freedom to include whatever score scaling they would like. However, this approach neglects the items themselves. Therefore, the thought and impact of decisions made

during the process of designing the items is not accounted for, which means that instruments are not able to be iterated on or refined as any changes to the instruments changes the scale used by the statistical model to determine the “true score” of each respondent (Wilson, 2023).

Combining the useful ideas behind both approaches had historically been difficult as statistical models that could be compatible had not yet been fully realized. Early on, Thurstone (1925) attempted to provide a solution by matching a probability distribution of scores to a construct in plots that measure the percentage of students who answered correctly to a question as a function of their chronological ages. Thurstone (1928) later asserted that an instrument’s function and measurement scale should not be influenced by the object of the measurement, i.e., the construct. Rasch extended this assertion into the instrument’s items by arguing that items should be independent from the respondents who engage with them (Rasch, 1961).

Construct Modeling incorporates both approaches through the implementation of the statistical model known as the The Rasch Model (Wilson, 2023). The Rasch Model is outlined in Rasch 1960-1980 and explored in the work of Wright 1968, Wright 1977, and Fischer & Molenaar, 1995. At its most basic level, the Rasch Model can be used for dichotomous items which are items that are designed to be scored in two distinguishable categories (Wilson, 2023). In the dichotomous case, the relationship between the construct being measured and the item responses obtained from the instrument takes the form of describing the probability of an item response, X_i (either 0 for an “incorrect response to the item” or 1 for a “correct response to the item”), for an item i , as being statistically modeled as a function of the respondent location (θ) on the construct map and the “item location” (δ). The respondent location can be thought of as how much of the construct being measured the respondent is demonstrating through their item responses along the scale denoted by the Construct Map. The item location can be thought of as the amount of the construct each respondent is demonstrating through their item responses that is stemming from interacting with the item itself. To obtain an accurate measurement of the amount of a construct that a respondent actually has, the difference between the respondent location and the item location is taken ($\theta - \delta$) (Wilson, 2023).

Three separate expressions can be obtained based on the relationship between the respondent location and the item location. The first is when the respondent location and item location is equal ($\theta - \delta = 0$). The second is when the respondent location is more than the item location ($\theta - \delta > 0$). And lastly, when the respondent location is less than the item location ($\theta - \delta < 0$). As we are interested in the probability of specific responses to specific items from each respondent, we can posit that probability here is a function of the difference between the respondent location and the item location. For the dichotomous Rasch Model, this probability of response $X_i = 1$ for a respondent with location θ and item location δ can be written as:

$$Probability(X_i = 1 | \theta, \delta) = f(\theta - \delta)$$

Based on this definition of probability and the concepts underlying the Guttman Scaling and CTT, the complete Rasch Model Equation for a dichotomous case where

the respondent “answers the item correctly ($X_i = 1$)”, can be expressed as the following equation where the right hand side represents $f(\theta - \delta)$ (Wilson, 2023):

$$Probability(X_i = 1 | \theta, \delta) = \frac{e^{(\theta - \delta)}}{1 + e^{(\theta - \delta)}}$$

For the probability that the respondent “answers the item incorrectly ($X_i = 0$), the equation can be obtained by remembering that the two probabilities must equal to 1.

$$Probability(X_i = 1 | \theta, \delta) + Probability(X_i = 0 | \theta, \delta) = 1$$

By substituting for the probability $X_i = 1$ and solving:

$$Probability(X_i = 0 | \theta, \delta) = \frac{1}{1} - \frac{e^{(\theta - \delta)}}{1 + e^{(\theta - \delta)}}$$

$$Probability(X_i = 0 | \theta, \delta) = \frac{1}{1 + e^{(\theta - \delta)}}$$

The most important part of this equation, and thus the Rasch Model itself, is the difference between the respondent location and the item location ($\theta - \delta$). To define this in terms of mathematical units, we need to isolate them in the above equations. First, we note that “Odds” is the ratio of probabilities for all outcomes in an event.

$$Odds(X_i = 1 | \theta, \delta) = \frac{Probability(X_i = 1 | \theta, \delta)}{Probability(X_i = 0 | \theta, \delta)}$$

After some more substitutions and simplifications, we obtain:

$$Odds(X_i = 1 | \theta, \delta) = e^{(\theta - \delta)}$$

Taking the log of both sides of this equation, we define the units of measurement for the Rasch Model as “logits”, also known as the “log of the odds.”

$$\log(Odds(X_i = 1 | \theta, \delta)) = \theta - \delta$$

To summarize, addressing the limitations of Guttman Scaling and CTT by accounting for both the items themselves in the instrument and the scores from respondents of those items, it parameterizes each individual response collected from the instrument, and statistically models the probability of observed responses instead of direct sum of responses which provides more flexibility for constructs to be measured and items to be designed (Wilson, 2023). A measurer has the added benefit of being able to simply visualize on a plot where each individual's respondent location is in

relation to one another and being able to compare where each individual's respondent location is in relation to the different items in the instrument by including representative curves for each item on the plot (Wilson, 2023). Utilization of the Rasch Model and appropriate calibration software, a measurer can generate a Wright Map that links the more qualitative Construct Map with the more empirical item responses from the respondents. As a final point, The Rasch Model is quite versatile, as it can also be expanded for polychotomous items by treating their scored responses as a series of dichotomous categorizations and comparing them (Category 1 vs Category 2, Category 2 vs Category 3, etc.) (Agresti, 1984; Masters, 1982; Wright & Masters, 1981; Wilson, 2023). The categories are usually defined and mapped based on the number of waypoints that are outlined in the Construct Map itself, but their probabilities must still total to 1. A detailed overview and mathematical derivation of the expansion of the Rasch Model is contained within Wilson (2023). The expansion of the Rasch Model also introduces parameters relating to item fit, respondent fit, and the critical points where there is a 50% chance that a respondent will be located at a higher grouping of categories rather than a lower grouping of categories (Thurstone Thresholds) (Adams et al., 2020). A more in-depth description of the fit parameters, with examples, will be covered in the *Results and Discussion* section of this chapter. We take advantage of the versatility of the Rasch Model, and by association *Construct Modeling*, for many of the constructs (factors) and items that we featured in BURET-TAMUS.

Item Response Theory

It is worth mentioning that work from other researchers have contributed to advancing our understanding of measurement and instrument development via their own theories and statistical models (Bock, 1972; Lord, & Novick, 1968; Lord, 1952; Rasch, 1961; Samejima, 1969; Samejima, 1972; Thurstone, 1925; van der Linden, 2018; Wright, 1977). Recall that the fundamental flaw with Guttman Scaling was its strict limitations it places on the items and the fundamental flaw with CTT was that the relationship between the construct and the items in the instrument was not accounted for (Wilson, 2023). The idea of solving this measurement issue and the subsequent development of approaches to devise a solution can broadly be considered to make up *Item Response Theory* (IRT). Approaches in IRT treat the response of each individual measured as a probabilistic outcome that can be statistically modeled based on estimated parameters that are related to the construct, item locations, and respondent locations (van der Linden, 2018). We have already described *Construct Modeling* as one approach in IRT (which selects the Rasch Model as its statistical model).

Other noteworthy approaches in IRT include: *Nominal Categories* which accounts for items that can be responded to multiple times during a measurement and scored in different categories in no particular order (select all that apply). It uses a multivariate logistic probability distribution model for the responses (Bock, 1972; Bock, 1997; van der Linden, 2018). The *Partial Credit Model* (PCM) is effectively the expanded Rasch Model that was covered in the previous sub-section and benefits from the Rasch Model's relative simplicity compared to other approaches in IRT that are used for polychotomous items such as those that are in multiple-choice format (Andersen, 1977; Masters, 1982; Rasch, 1977; Wilson, 2023). The *Rasch Scaling Model* (RSM) is used

for responses from items that are in ordered, successive categories such as those in “Strongly Disagree to Strongly Agree” items or frequency “Never to Always” (Andersen, 1977; Andrich, 2005; Rasch, 1961; Wilson, 2023). These types of items are also known as Likert items (Likert, 1932). As the name implies, RSM uses a modified form of the Rasch Model as its statistical model. Free-response items can be qualitatively scored and categorized for use in an appropriate IRT model.

We have briefly described other approaches in IRT in this sub-section, as we have explored them all to differing extents during the analysis of constructs, items, and responses in BURET-TAMUS. *Construct Modeling* is our primary approach that is used in this chapter, but due to the varying amount of research factors (constructs) that are measured, item types, and responses, it is valuable to at least consider and put certain items and research factors through the other approaches to aid in interpreting the data that we collected with BURET-TAMUS. More information about the Construct Maps, Items Design, and Outcome Spaces is provided in the *Background* section.

Multidimensionality

In the *Introduction and Motivation* section, we stated our interest in determining the connections between different research factors and how they affect how students are experiencing teaching and mentoring practices in research along with learning more about how these factors interplay with each other to shape the student experience in UREs. With this insight, we can gain a more detailed interpretation of the data that we collect from students. There is a special variation of the Rasch Model that we utilize in this project to attempt to satisfy this interest. It is used in Multidimensional Item Response Theory (MIRT).

MIRT extends IRT for situations where item responses for a given item is influenced by multiple constructs rather than just one as in the unidimensional situation. An example, further described in Briggs & Wilson 2003, lies in an instrument that is attempting to measure the construct, “College Readiness.” This construct can be considered multidimensional because “College Readiness” can be deconstructed to be dependent on measurement of sub-constructs such as “SAT Math Performance” and “SAT Verbal Performance.” The sub-constructs have their own item sets and Construct Maps. Taking measurements of constructs and respondents in this fashion can offer some interesting benefits (Wilson, 2023). The first is that there are statistical advantages with MIRT because accounting for other constructs that influence the item response leads to improved and more accurate model fitting, greater flexibility in item design, and greater precision of respondent location across various constructs. Another benefit is that interpretation of results are more nuanced and specific to the individuals that are measured. However, the benefits come at the slight loss of the intuitiveness and simplicity of the standard unidimensional Rasch Model.

Similar to IRT, there are many different approaches and statistical models under the figurative MIRT umbrella. The different models can be categorized based on whether they look at the relationship **between-item** or **within-item** (Adams, Wilson, & Wang, 1997; Wilson, 2023). In the **between-item** case, the model is looking at how different constructs are being measured across different items. **Within-item** looks at how different constructs are influencing responses in a specific item. Later in this

chapter, we explore the multidimensionality of our constructs more in-depth. We analyze **between-item** when we investigate the relationship between the items and responses of the specific research factors we tested on BURET-TAMUS (See *Background* section). We analyze **within-item** when we analyze how the specific items for teaching and mentoring practices students experience in UREs are being influenced by the other factors we tested for in BURET-TAMUS.

Between-item MIRT enables an additional parameter to be obtained: The MIRT Correlation Coefficient (ζ). The correlation coefficient describes the extent to which the different constructs being measured in an instrument are allowed to be mathematically correlated (Wilson, 2023). This is under the assumption that someone's respondent location in one construct can be used to predict their respondent location in another construct. Typically, these are obtained within MIRT models by generating covariance matrices from the item responses. Interpretation of results from an MIRT measurement can be greatly enhanced with the correlation coefficient. In this project, we briefly explore the correlation of different factors featured in BURET-TAMUS.

Background

As mentioned in the *Introduction and Motivation* section, we were interested in measuring various factors that are affecting how students experience UREs and how they affect teaching and mentoring practices in that context. We are also investigating how different research factors correlate or influence each other and student outcomes in URES. However, there are many factors that can shape the student experience in URES (Coté, 2024; Linn et al., 2015), and it would not be logistically feasible to develop an instrument that attempts to measure all of them. Thus, we decided on factors that would be commonly experienced by students, despite the lack of homogeneity in URES (Blockus et al., 1997; Crowe & Brakke, 2008; Kardash, 2000), and would attempt to account for as many external variables as possible. In addition, we opted to include factors in BURET-TAMUS that would be well-suited to the *Construct Modeling* approach that we discussed in the *Theoretical and Other Frameworks* section. The factors included in BURET-TAMUS were: 1) URE Structure 2) Mentor-Mentee Dynamics 3) Student Exposure to Teaching and Mentoring Practices 4) Student Confidence and STEM Identity 5) Student Past and Lived Experiences 6) Research Motivations 7) Integration into Academia.

In this section, we provide an overview of the literature of what is known about how several significant research factors influence student experiences in UREs and how we use that information to inform our underlying approach to creating Construct Maps and items for those factors in BURET-TAMUS. For the purposes of this project and to align with the tenants of *Construct Modeling* (See the *Theoretical and Other Frameworks* section), we treat each factor as a separate construct with its own item sets in BURET-TAMUS. We begin this section with an overview of the literature on teaching and mentoring practices in UREs.

Teaching and mentoring are often conflated with each other in the literature. We believe that in order to evaluate teaching and mentoring, we need a clear definition of each. In the development of BURET-TAMUS, we treated “teaching” and “mentoring” as distinct constructs, but acknowledge that there may be some overlap in the actions and

intentions that are typical of using each. We also acknowledge that certain aspects of teaching and mentoring occur in-tandem and at times they may have some influence over each other during measurement.

In the literature, there is not a universally-used definition to describe what teaching looks like in UREs. However, there has been comprehensive work by researchers and STEM educators that have led to consensus on teaching practices in UREs. Here, we cover a few examples of common teaching practices that are used by research mentors in UREs that have appeared in the literature: 1) Teach undergraduate students critical STEM content knowledge so that the students can connect this knowledge to carry out the research project (Bixby & Miliauskas, 2022; Coté, 2024; Freeman et al., 2023; Kerr & Yan, 2016; Olimpo, Fischer, & DeChenne-Peters, 2016). 2) Teach undergraduate students technical lab skills and research protocols necessary to achieve the goals of the research project (Bauer & Bennett, 2003; Craney et al., 2011; Linn et al., 2015; Kardash, 2000; Rowland et al., 2012; Tan, Elkin, & Satagopan, 2022; Trott et al., 2020; Zydney et al., 2002). 3) Teach undergraduates to “think like a scientist” through development of critical thinking skills, data analysis, and interpretation of results (Bixby & Miliauskas, 2022; Brownell et al., 2015; Faber et al., 2020; Helix et al., 2022; Hunter, Laursen, & Seymour, 2007; Jordan et al., 2014; Linn et al., 2015; Rowland et al., 2012) 4) Teach undergraduates to scientifically communicate through public speaking and creation of research artifacts that disseminate the findings of the research project and/or research experience (Auchincloss et al., 2014; Eagan et al., 2011; Faber et al., 2020; Helix et al., 2022; Linn et al., 2015; Ryder, Leach, & Driver, 1999; Seymour et al., 2004; Zydney et al., 2002).

These teaching practices are understood to facilitate active learning in the URE, meaning that the student is actively engaged in a learning environment and processes that build critical thinking, problem-solving skills, and research independence (Bonwell & Eison; Brame, 2016; Felder & Brent, 2009). Therefore, researchers have acknowledged that a teaching approach for undergraduate students in STEM should involve practices and actions that promote active learning, and engagement with scientific inquiry (Freeman et al., 2014; Kuh, 2008). Other researchers, on the other hand, have argued that teaching in UREs should be distinguished from other avenues of STEM education due to the different contexts and goals that are inherent in research experiences (Dancy, Henderson, & Smith, 2014; Hu et al., 2008; National Academies of Sciences, Engineering, and Medicine, 2016; Tormey et al., 2021; VanWyngaarden et al., 2024). Some researchers have noted that UREs are designed around achieving certain outcomes within students rather than established teaching approaches or frameworks (Auchincloss et al., 2014; Krim et al., 2019; Linn et al., 2015). To attempt to bridge the gap between these numerous perspectives, for the purposes of this project, we will define teaching in UREs as **a series of practices, activities, or approaches that help students learn STEM content knowledge, technical lab skills, research protocols, and scientific communication as active learners as necessary to develop them as independent scientists on a research project in accordance to their needs and goals**. This definition informs our Construct Map and Items Design related to undergraduate learning in UREs as reported by students who were measured in BURET-TAMUS (See *Methods* and *Results and Discussion* section for more information).

Research mentoring is also lacking a universally-used definition in the context of UREs (Crisp & Cruz, 2009; Dawson, 2014; Jacobi, 1991). In addition, the effectiveness and approach towards research mentoring “varies substantially” in UREs according to a 2015 review by Linn et al.. This adds difficulties for evaluating the effectiveness of UREs, training research mentors, and designing studies to study research mentoring (Coté, 2024; Crisp, 2009; Linn et al., 2015; Lopatto, 2004; National Academies of Sciences, Engineering, & Medicine, 2018). In fact, many studies in this area do not even propose a definition of mentoring that they are using or provide one to the participants that are asked about it in their studies (Mullen & Kilmaitis, 2021), which complicates comparisons between them. Fortunately, there is an abundance of literature that explores and evaluates common mentoring practices that have been shown to be beneficial to student outcomes and development. Understanding commonly used research mentoring practices in the literature are helpful to arrive at a definition that we can use for this project.

We now provide an overview of some common mentoring practices that have been used by research mentors in the literature or studied in literature that feature UREs: 1) Foster the research mentee’s independence over time on a research project through appropriate time investment and guidance (Coté, 2024; Faber et al., 2020; Goodwin et al., 2023; González; 2006; Hanauer & Dolan, 2014; Johnson & Harreld, 2012; Linn et al., 2015; Shanahan et al., 2015; Vasquez-Salgado et al., 2023; Walkington et al., 2019). 2) Helping the mentee achieve academic and career goals through research engagement (Coté, 2024; Haeger & Fresquez, 2016; Pfund et al., 2016; Trott et al., 2020). 3) Provide psychosocial support related to nurturing the mentee’s confidence and scientific identity by collaborating together in the URE (Bixby & Miliauskas, 2022; Bradshaw et al., 2023; Coté, 2024; Ehrich, Hansford, & Tennent, 2004; Estrada et al., 2018; Fletcher & Mullen, 2012; Goodwin et al., 2023; Gray, 2000; Haeger & Fresquez, 2016; Hakim, 1998; Kardash, 2000; Kram, 1983; National Academies of Science, Engineering, and Medicine, 1997; Olimpo, Fischer, & DeChenne-Peters, 2016; Shanahan et al., 2015; Shellito et al., 2001; Walkington et al., 2019; Yaffe, Bender, & Sechrest, 2012). 4) Integrate the mentee into the lab environment and cultivate their academic network (Campbell & Campbell, 2007; Coté, 2024; Davis, 2007; Ishiyama, 2007; Mabrouk, 2009; National Academies of Science, Engineering, & Medicine, 1997; Romero, Polhemus, & Saubolle-Camacho, 2023; Shanahan et al., 2015; Trott et al., 2020; Walkington et al., 2019; Zydney et al., 2002). 5) Communicate effectively and mutually align the mentor’s and mentee’s expectations and goals to the research project (Coté, 2024; Gray, 2000; Linn et al., 2015; Malachowski, 1996; Schultz, 2001; Shanahan et al., 2015; Shellito et al., 2001; Walkington et al., 2019).

From these studies and the work of Coté (2024), we have developed a definition of mentoring in UREs which is as follows: **A series of supporting activities, time investment, and mentoring practices that a mentor partakes in during their serious and collaborative relationship with a mentee, where the mentee is intellectually engaged in a research experience so that the mentee may achieve their goals, meet the mentor’s expectations, and further develop themselves as an academic researcher in the STEM community.** Construct Maps and Items Design related to mentoring practices were created and scaled in BURET-TAMUS based on the

extent of the investment and support the research mentor was able to provide to the student (according to the students themselves) across the utilization of several mentoring practices. See *Methods* and *Results and Discussion* section for more information.

We define “URE Structure” as the **“The academic or professional context through which a student engages with a URE.”** The literature indicates that there are several different types of UREs available for students to engage with, such as Course-Based Undergraduate Research Experiences (CUREs), where students engage with a research project that promotes “discovery” in a classroom setting, typically over the course of several weeks in a laboratory course (Auchincloss et al., 2014; Buchanan & Fischer, 2022; Coté, 2024, Linn et al., 2015; Krim et al., 2019). The amount of time that students can work on a research project, the expectations of the mentee, and the individual that serves as the mentee’s mentor is heavily dependent on the URE structure (Auchincloss et al., 2014; Coté, 2024; Deka, Shereen, & Wand, 2023; Haeger & Fresquez, 2016; Hernandez et al., 2018; Jordan et al., 2014; Kerr & Yan, 2016; Spence et al., 2022; Sun et al., 2022; Tan, Elkin, & Satagopan, 2022; UC Regents, 2023; Zydney et al., 2002). Therefore, we can expect that the student experience with a URE can fluctuate significantly based on the circumstances of the URE structure. For BURET-TAMUS, we treated the Construct Map for URE Structure as a simple categorization for respondents based on the context of their most UREs.

The type of working relationship and frequency of interactions that mentees can have with their mentors, i.e., the Mentor-Mentee Dynamics, is also important to the student experience in UREs. In most UREs that take place in a faculty’s research lab, graduate students or post-doctoral scholars are often assigned to work with and mentor an undergraduate student on a research project (Aikens et al., 2016; Ann Mabrouk & Gapud Remijan, 2023; Coté, 2024; Dolan & Johnson, 2010). In CUREs, a faculty member or student instructor often supervises and supports students as they engage in a research project (Auchincloss et al., 2014; Freeman et al., 2023, Goodwin et al., 2023; Shortlidge et al., 2016). Regardless, different individuals will provide varying levels of support and time investment to mentees in a research project based on their mentoring approach, their expectations, their overall level of experience working with students, and their other academic and personal responsibilities (Atkins et al., 2020; Coté et al., 2025; Coté, 2024; Freeman et al., 2023; Haeger & Fresquez, 2016; Linn et al., 2015; Shortlidge et al., 2016.) Numerous studies have indicated that a close and productive dynamic between the mentor and mentee can help contribute to the positive outcomes associated with UREs (Auchincloss et al., 2014; Bixby & Miliauskas, 2022; Freeman et al., 2023; Krim et al., 2019; Nolan et al., 2020; Olimpo, Fischer, & DeChenne-Peters, 2016; Robnett et al., 2015; Zydney et al., 2002). For students from historically excluded groups in STEM, having a positive dynamic with their research mentor has been shown to positively affect the achievements and aspirations of these students (Atkins et al., 2020; Coté, 2024; Crisp & Cruz, 2010; Delgado-Guerro & Gloria, 2023; Goodwin et al., 2023; Morales, Grineski, & Collins, 2021; Romero, Polhemus, & Saubolle-Camacho, 2023; Trott et al., 2020). To obtain a clear picture of what students are going through when they participate in UREs and to gain more context on the other factors featured in BURET-TAMUS (Student Exposure to Teaching and Mentoring Practices in particular), we scaled the Construct Map for Mentor-Mentee Dynamics

based on how “closely” students indicated they were able to work with their primary research mentors (the individual tasked with mentoring the student on a research project).

Each student has their own set of intrinsic and extrinsic motivations for participating in UREs. Intrinsic motivations are those that drive individuals for personal satisfaction and fulfillment. Extrinsic motivations are those that are based on achieving some sort of external goal (Hennessy et al., 2015). For example, many students who participate in UREs do so to at the onset to gain valuable experience for their desired careers, to learn useful skills, or to prepare for future academic opportunities (Coté et al., 2025; Craney et al., 2011; Hess et al., 2023; Trott et al., 2020; Vasquez-Salgado et al., 2023). With the Research Motivations factor in BURET-TAMUS, we developed Construct Maps based on whether students had intrinsic and/or extrinsic motivations for engaging in research. Items were developed to categorize the students based on motivations and we also attempted to learn more about how these motivations might have changed over time.

The amount of confidence that students enter a URE with and their conceptualization of themselves as scientists and members of the scientific community, can affect several aspects of their research experiences. We measure this in BURET-TAMUS (Student Confidence and STEM Identity) through looking at the extent to which they felt included in their research labs (or didn't) in the Construct Map for STEM Identity and whether or not they became more confident researchers after participating in UREs in the Construct Map for Student Confidence. The literature has suggested that some students who participate in UREs feel more confident and prepared for science careers afterwards (Coté et al., 2025; Gamage et al., 2022; Linn et al., 2015; Ovink & Veazey, 2011; Strawn & Livelybrooks, 2012; Taraban & Rogue, 2012; Trott et al., 2020). In other studies, students have attributed their UREs as helping to cultivate and foster their STEM identities (Bixby & Miliauskas, 2022; Feldman, Divoll, Rogan-Kylve, 2013; Grunert & Bodner, 2011; Harrison et al., 2011; Linn et al., 2015; National Academies of Science, Engineering, and Medicine, 1997; Ovink & Veazey, 2011; Pawson, 2004; Vasquez-Salgado et al., 2023). We expect this factor to have a heavy amount of influence on the other factors due to the fact that most students are already at a formative stage in their lives when they engage in a URE so their development of confidence and STEM identity will be fresh in their minds as a significant research takeaway and thus, frame a lot of their responses throughout BURET-TAMUS.

Some students enter UREs with skills or knowledge obtained from past research experiences (lab skills, communication skills, discipline content knowledge) or their personal lived experiences (ability to collaborate with others, speaking multiple languages, personal networks, professional training, etc.) that help their success in the research experience (Camacho et al., 2021; Cobian et al., 2024; Denton & Barrego, 2021; Eseban-Guilbert & Moll, 2014; Wilson et al., 2016). Therefore, we implemented the Student Past and Lived Experiences factor in BURET-TAMUS. The Construct Map for this factor outlines a scale where one end is a student strongly indicating that their past and lived experiences assisted them in a research experience and the other end of the scale indicates that it had no effect.

The final factor we tried to measure in BURET-TAMUS was that of Integration into Academia. We conceptualize this as: **The extent and specifics to which students discover and engage with new professional and academic opportunities in STEM academia as a direct result of participating in UREs.** The literature has shown that students who participate in UREs are often exposed to professional and academic opportunities that shape the way they reflect on their UREs and change how they engage with UREs (Coté, 2024; Haeger et al., 2024; Hernandez et al., 2018; Krim et al., 2019; Romero, Polhemus, Saubolle-Camacho, 2023; Tan, Elkin, & Satagopan, 2022). Here, we scale this factor in its BURET-TAMUS Construct Map based on how much more "integrated" the student became in their academic or professional communities/networks compared to their "integration" prior to having a URE.

We hypothesize that the student experience in a typical URE is a multi-dimensional experience where student learning and mentoring are influenced by the aforementioned factors working in tandem and with integration of each other. We propose to measure the research experience of undergraduate students across these individual factors via our survey instrument that was designed with the *Construct Modeling* approach (See *Theoretical and Other Frameworks* section) to gain more insight into the student experience. Our instrument should help to qualitatively identify/describe effective teaching and mentoring practices (or commonly expressed beneficial factors) in UREs and quantify the extent to which they interplay with the other factors. We describe the instrument development, our student sample, survey administration, and data collection in more detail in the *Methods* section.

Methods

A survey was selected instead of other types of instruments as it is more accessible to collect responses from our intended sample and allows us to analyze data through the *Construct Modeling* approach. Recall that in *Construct Modeling*, an instrument must contain four "building blocks" that build and iterate on each other. These are the Construct Map, the Items Design, the Outcome Space, and the Wright Map. Refer to the *Theoretical and Other Frameworks* section for a full explanation of each building block. In this section, we provide a breakdown of the design and rationale for some of the Construct Maps, Item Designs, and Outcome Spaces used in BURET-TAMUS. Examples of Wright Maps are saved for the *Results and Discussion* section.

Construct Maps

As an example, we have provided the construct maps that were designed to measure the undergraduate teaching and mentoring practices experienced by our sample. Figure 2.1 consists of the Teaching Construct Map used in this study. In the early stages of instrument development, we understood from prior work regarding UREs that students who participate in research are subject to a plethora of variables that could influence the teaching their mentors may provide to them. The teaching construct map aims to measure this through 5 waypoints. These 5 waypoints (ordered in terms of increasing student agency and integration with other reported teaching practices

students experienced across all items in this section of the survey) are *Absent*, *Self-reliant*, *Teacher-Centered*, *Instructional Blend*, and *Student-Centered*. The *Student-Centered*, *Instructional Blend*, and *Teacher-Centered* waypoints describe change in teaching. Waypoint 5 corresponds to *Student-Centered* on the Teaching Construct map. Respondents who experience teaching at this level have felt a high level of agency. They felt that their mentor taught in a fashion where they were active learners, had their needs acknowledged, and were enabled to further their mastery on a subject. Waypoint 4 corresponds to *Instructional Blend*. Respondents who experience teaching at this level have a mix of teaching that allows them to exhibit agency and teaching that is more traditional or teacher-centered. Waypoint 3 corresponds to *Teacher-Centered*. Respondents who experience teaching at this level have felt a low level of agency. They felt that their mentor taught in a fashion where they were more passive learners, and consisted of traditional instruction methods such as lectures or demonstrations. Waypoint 2 corresponds to *Self-reliant*. At this level, respondents indicate that they had little to no teaching in their research experience or had so little guidance from their mentor to the point where they instructed themselves on the research aspect. Waypoint 1 corresponds to *Absent*. At this level, respondents indicate that they were taught a particular research aspect or that they did not have a primary research mentor.

Waypoint Level	Description
Student Centered (Waypoint 5)	The mentee's experience when being taught this research aspect by their research mentor was that the mentor facilitated the mentee to develop their own understanding or explanations. The mentor guides students to learn skills or techniques through their own engagement and helps them develop mastery over time and foster independence. The mentee feels that the instruction considers their needs, experience, and personal background.
Instructional Blend (Waypoint 4)	Some qualities of teacher centered and student centered instruction are experienced by the mentee per instance or over time.
Teacher Centered (Waypoint 3)	The mentee's experience when being taught this research aspect by their research mentor was that it primarily consisted of direct lectures, demonstrations, or explanations from their mentors. Mentee's experience is more passive or with little agency over the instruction.
Self-reliant (Waypoint 2)	The mentee's experience with this research aspect was that they were expected or needed to teach themselves the research aspect without guidance from their mentors.
Absent (Waypoint 1)	The mentee was not taught about this aspect of research, it was not applicable to them, or they did not have a research mentor.

Figure 2.1. Teaching Construct Map

Figure 2.2 consists of the Mentoring Construct Map. The construct map design for mentoring is centered around how supported mentee's feel the mentor is towards their development as scientists in the URE. Based on the prior work of this research group, we believe this support is one of the most critical facets towards an effective mentoring relationship in UREs. Mentoring, at the highest level of this construct map, should effectively support the students' needs for development and integrate common mentoring practices to cultivate an environment for said development. The mentoring construct map aims to measure this across 5 waypoints. These 5 waypoints (ordered in terms of increasing mentor support that fosters student development) are *Absent*, *Isolating*, *Adequate*, *Nurturing*, and *Flourishing*. The *Flourishing*, *Nurturing*, *Adequate*, and *Isolating* waypoints describe the change of mentoring support that mentee's indicate. Waypoint 5 corresponds to *Flourishing* on the mentoring construct map. Respondents at this level have experienced mentoring that was effective and meant their needs, goals, and background. In addition, they felt that they experienced mentoring that created a very favorable research environment and mentoring relationship where they could thrive in terms of scientific development. Waypoint 4 corresponds to *Nurturing*. Respondents at this level have experienced mentoring that was effective for their goals and that their mentor provided appropriate levels of support for them. Waypoint 3 corresponds to *Adequate*. Respondents at this level have experienced mentoring support or a mentoring relationship that was basic or "just enough" to meet the mentee's goals. Waypoint 2 corresponds to *Isolating*. At this level, respondents indicate that the mentoring support was ineffective, infrequent, or without much consideration of the mentee's needs. In addition, the mentee feels that their mentoring relationship or research environment saw little growth. Waypoint 1 corresponds to *Absent*. At this level, respondents indicate that they did not receive mentoring support from a primary mentor figure.

Waypoint Level	Description
Flourishing (Waypoint 5)	The mentee's experience when their mentor used this mentoring practice was that it was very effective in terms of supporting the mentee's needs, goals, and experience levels while also creating a work environment and fostering a mentoring relationship where the mentee felt that their development could thrive.
Nurturing (Waypoint 4)	The mentee's experience when their mentor used this mentoring practice was that it was applied effectively, helped to increase the connection between themselves and the mentor, and/or provided support that was appropriate to the mentee's goals, needs, or experience levels.
Adequate (Waypoint 3)	The mentee's experience when their mentor used this mentoring practice was that it was applied effectively when appropriate. The mentee might feel a basic connection and level of support with their mentor. The mentee feels that their mentor is involved with them to a degree which maintains the mentoring relationship.
Isolating (Waypoint 2)	The mentee's experience when their mentor used this mentoring practice was that it was applied ineffectively, infrequently, or without much consideration of the mentee's needs or feedback. The mentee might also experience a lack of connection with their mentee or a lack of support.

Absent (Waypoint 1)	This mentoring practice was not employed, not applicable to the student, or they did not have a research mentor.
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Figure 2.2. Mentoring Construct Map

The other factors of undergraduate research experiences that we have decided to measure with our survey instrument follow a similar format.

Survey Item Designs and Outcome Spaces

After designing and coming to a consensus on the construct maps for each factor in the survey, we next began to design item sets for each one. To review, items are components of an instrument that elicit a response from the study participants that can be measured across the scale of waypoints as outlined in the appropriate construct maps. In the case of this survey instrument, items come in the form of survey questions that ask how students experienced each research factor in their UREs.

For item design, we had to take into account that undergraduate students from a wide range of backgrounds and individual UREs needed to be able to respond to each item without much difficulty. We also had to keep a delicate balance in the types of items that would be featured in the survey and how intensive we would ask the response to be to avoid survey fatigue. Outcome Spaces were dependent on the type of item and we introduced that variety in the Outcome Spaces so that we can observe and account for which types of items students would have more difficulty with answering. We did not place an equal number of items for each research factor featured in the survey as there are some research factors that require more items to get insightful data from and because we expect some research factors to be more significant to student experiences in research than others. In addition, we needed to design items that we could validate through survey exit interviews which are described further in a later section. Survey item groups for each factor had to also be reasonably expected to consistently elicit responses that we can measure across the appropriate and pre-determined construct maps as mentioned in the previous paragraph while minimizing influence or overlap in measurement from other research factors. Finally, we needed to make sure that the survey length was not overwhelmingly long so that it could be completed within a reasonable amount of time.

Under these criteria and restrictions, we designed a total of 58 items in our survey. 3 items for ***Structure of URE***, 5 items for ***Mentor-Mentee Dynamics***, 10 items for ***Teaching & Mentoring Practice Exposure***, 12 items for ***Student STEM Identity & Confidence***, 6 items for ***Student Past and Lived Experiences***, 3 items for ***Research Motivations***, 5 items for ***Integration into Academia***, and 14 ***Demographic Items***. Of the 44 non-demographic items, 19 were multiple choice questions, 4 were Likert-style items, and 21 were open response questions. Items for each factor were grouped together in separate sections throughout the survey. A list of every item designed and featured in this survey instrument can be found in the *Appendices*.

Survey Administration

The survey was created between September and November 2024 on a Berkeley licensed version of Qualtrics. Qualtrics was used to administer the survey electronically through a direct link online. Prior to beginning the survey, students were provided an electronic consent form with full details of the study, commitment requested from the students, and what data would be collected from the students. Qualtrics was chosen for these purposes due to familiarity with the tool and for how it secures and stores survey data. The procedures featured in this study were approved by the University of California, Berkeley Committee for Protection of Human Subjects, Protocol #2023-11-16931. Approval for the study was obtained on December 1st, 2023. Data collection began in December 2024 and lasted approximately 2 weeks.

Data Storage

Data on Qualtrics is stored in a specific location; it does not float around in the “cloud”. In addition, all data is processed in that location, and is not moved to any other jurisdictional area. Qualtrics uses Transport Layer Security (TLS) encryption (also known as HTTPS) for all transmitted data. Survey on Qualtrics can be protected with passwords and HTTP referrer checking. Qualtrics services are hosted by trusted data centers that are independently audited using the industry standard SSAE-16 method. Qualtrics meets or exceeds the minimum requirements as outlined in FIPS Publication 200.

Survey data was stored on a UC Berkeley licensed Box account. The survey data is coded by creating a unique, random code for each participant. A key was created that links the random codes to identifying data. The key is stored and kept secured on Box separately from the survey data. The researchers are the only individuals who have access to identifying data on Box. Data and keys stored on Box are to be deleted 3 years after completion of this study.

Participant IP addresses were not collected in this study. Participants were also recommended to clear their browser’s history, cache, cookies, and other browsing data upon completion of the survey. Participation was voluntary and participants were able to decline or withdraw their participation at any point. There is minimal risk associated with participation in this study.

Alternate Survey (Experimental Control)

An “Alternate Survey” was also developed alongside BURET-TAMUS. This survey was designed to measure a control group in our study. In this case, students who would have access to BURET-TAMUS during its administration, but who have not engaged in a URE would be instructed to complete this Alternate Survey. The Alternate Survey was also administered through a separate Qualtrics form online and consent was obtained through a similar form prior to entering the survey. Students were offered the same compensation and opportunity to participate in the survey exit interviews. Data collection and storage followed the protocol that was used for the data collected from BURET-TAMUS.

Since this Alternate Survey would be for students that did not have research experience, the constructs and items featured needed to be modified somewhat. We

opted for a focus on the students' experience conducting hands-on STEM work under the guidance of an instructor in their STEM courses. Therefore, this survey emphasized undergraduate teaching from the students' perspective. Constructs were redesigned to be in line with this new context and items were rewritten to elicit a response from the student's experience in the classroom/teaching labs. Some constructs and items from BURET-TAMUS were not compatible with measuring students' experiences in their STEM coursework or could not be separated from the URE context. Thus, they were removed from the Alternate Survey.

We designed a total of 42 items for the Alternate Survey. The featured constructs and item total for each one is: 2 items for **Course Structure**, 3 items for **Teaching Practice in STEM**, 11 items for **Student STEM Identity and Confidence**, 7 items for **Student Past and Lived Experiences**, 5 items for **Integration into Academia**, and 14 **Demographic Items**. Of the 28 non-demographic items, 2 were Likert-style items, 11 were multiple-choice questions, and 15 were open response questions. Items for each construct were grouped together in different sections of the Alternate Survey. A full list and further details of the items featured in the Alternate Survey can be found in the *Appendices*.

Survey Sample and Recruitment

The final sample (those who fully completed the main survey with genuine answers) for this study consisted of seventy-five undergraduate students in CHEM 135 [Chemical Biology] at UC Berkeley. For reference, thirty-eight students completed the Alternate Survey. Students were recruited via their course website and were offered extra credit for the course as compensation for their participation. When providing consent for participation in the research survey, students were also able to indicate consent for a survey exit interview with a member of the research team after the survey data collection closed.

Study Compensation

Each student that fully completed the survey (either the main survey or the alternate survey) on time and with genuine answers were given compensation in the form of extra credit for the course. For participation in a survey exit interview, participants were offered a \$25 gift card. 9 students completed a survey exit interview.

Exit Interviews

In the survey exit interviews, students were asked to provide more context and details for their response to several items in either BURET-TAMUS or the Alternate Survey. We also collected feedback on the student experience taking the survey. Students were provided the opportunity to validate their responses to certain items in each survey. Most interviews took place over a UC Berkeley Zoom call and lasted about 30-45 minutes. As with the survey data, interview data was stored, transcribed, and deidentified under a similar protocol. The semi-structured survey exit interview protocol can be found in full in the *Appendices*.

Statistical Model in RStudio and BASS Calibration

We utilized RStudio (version 2025.092 + 418) for data analysis. After the completion of data collection, the data from the survey was coded and downloaded onto a spreadsheet. This spreadsheet was split into multiple spreadsheets. One contained the responses for the teaching items, one contained the responses for the mentoring items and another contained all of the responses from each factor together. Each spreadsheet was imported into the Berkeley Assessment System Software (BASS) for calibration.

It is possible to fit the survey data through a variety of different statistical models. In this study, we placed emphasis on the Rasch Model during the calibration process. The Rasch Model is intended to fit data from dichotomous items (items scored between only two categories/waypoints) (Rasch, 1997). In the Rasch Model, the probability of the item response for a particular item X is modeled as a function of the respondent location on the construct map as θ and the item's "difficulty" as δ (Rasch, 1960-1980). A deeper description of the dichotomous Rasch Model and the derivation of the units for this model, "logits," are in the *Theoretical and Other Frameworks* section.

As our data was polytomous in nature as opposed to dichotomous, the Rasch Model in our data analysis was extended through treating our different construct map waypoints and item responses scores as a series of dichotomous characterizations. These characterizations are ordered as adjacent contrasts (**W1** vs. **W2**, **W2** vs. **W3**,....) as it provides information about how responses transition between waypoints and allows us to more readily compare them (Agresti, 1984). This extension of Rasch sets up the foundation for a Multidimensional analysis involving several different factors of interest (MIRT). The benefits of MIRT is that it can reflect the presence of latent variables in the data, provide better item fits, and help with data interpretation. MIRT can also lead to a more nuanced understanding of results per individual by estimating the effects multiple latent variables have on the score simultaneously. Latent variables are "hidden factors" that might influence the factors that we measured, but weren't actually measured themselves.

Since we are working more than 3 factors, we are using the following MIRT model in our study (Birnbaum, 1968):

$$\Phi(x_{ij} = 1 | \theta_i, \alpha_j, d_j, \gamma_j) = \gamma_j + \frac{(1 - \gamma_j)}{1 + \exp[-D(\alpha_j^T \theta_i + d_j)]} \quad (1)$$

Where i is the distinct participants, j is the test items, θ represents latent factors, α is the associated item slopes, d is the item intercept, γ is the guessing parameter, and D is the scaling parameter. In RStudio, this is one of many MIRT models available to use within the *mirt* package. Further details of the *mirt* model can be found in the work of Chalmers 2012. When coding in RStudio, we determined a test number of latent variables via Exploratory Factor Analysis (EFA) which is described in further detail later in this paper.

Here, we define calibration as the empirical and informational process performed on a measuring instrument for establishing a functional relation between the local scale

of the instrument and a public scale (Mari, Wilson, & Maul, 2023). The Berkeley Assessment System Software (BASS) was developed by Dr. Mark Wilson and his collaborators. BASS is capable of computing several statistical parameters and fitting data once the user inputs Constructs Maps, items, and the Outcome Space. To obtain this, BASS is programmed to fit data under the Rasch Model after a calibration step. BASS completed the calibration for the BURET-TAMUS data and determined for each construct separation reliability coefficients (such as the expected a posteriori (EAP) and weighted mean likelihood estimate (WLE) coefficients), item parameter indices, fit indices, and Wright maps. These coefficients and indices can be used to investigate the reliability and validity of the instrument (See *Results and Discussion* for more information).

Limitations

We recognize selection bias as one limitation for this project. Selection bias in this context refers to student participation in BURET-TAMUS or the Alternate Survey being more skewed towards students who are already experiencing academic success or achievement. Thus, we do not make the argument that the student experiences or outcomes reported on from this study are generalizable to the wider undergraduate population at our institution or at a national level. We acknowledge that because of selection bias, the connotations of student responses may lean towards being more positive towards their UREs and their research mentors. To account for this, we focused on establishing trends and patterns between factors in our studies and describing teaching and mentoring practices in our study rather than focusing on evaluating research mentors or beneficial student outcomes.

Another limitation lies in our survey demographics (See *Appendices* for a full breakdown). While our institution supports and hosts students from a diverse range of backgrounds that stem from all around the world, we do not argue that the student sample featured in the Chemical Biology course at our institution is representative of the overall student population. Thus, we were unable to analyze our data or report generalizable trends of the student experience from those that are a part of historically excluded groups in higher education.

Results & Discussion

Interesting Student Responses by Item

Below we share the responses for each of the items across BURET-TAMUS. These were meant to serve as preliminary gauges into how students experienced research at their institution and helped to interpret the more advanced statistical data later in the analysis. Throughout this sub-section, we chose to only highlight the most interesting responses due to the sheer abundance of survey data collected. First, we show the student responses for the first 3 questions of the survey which made up the *URE Structure Factor*.

URE Structure (Items 1-3)

Q1. Have you had or are currently in a research experience? Select all that apply

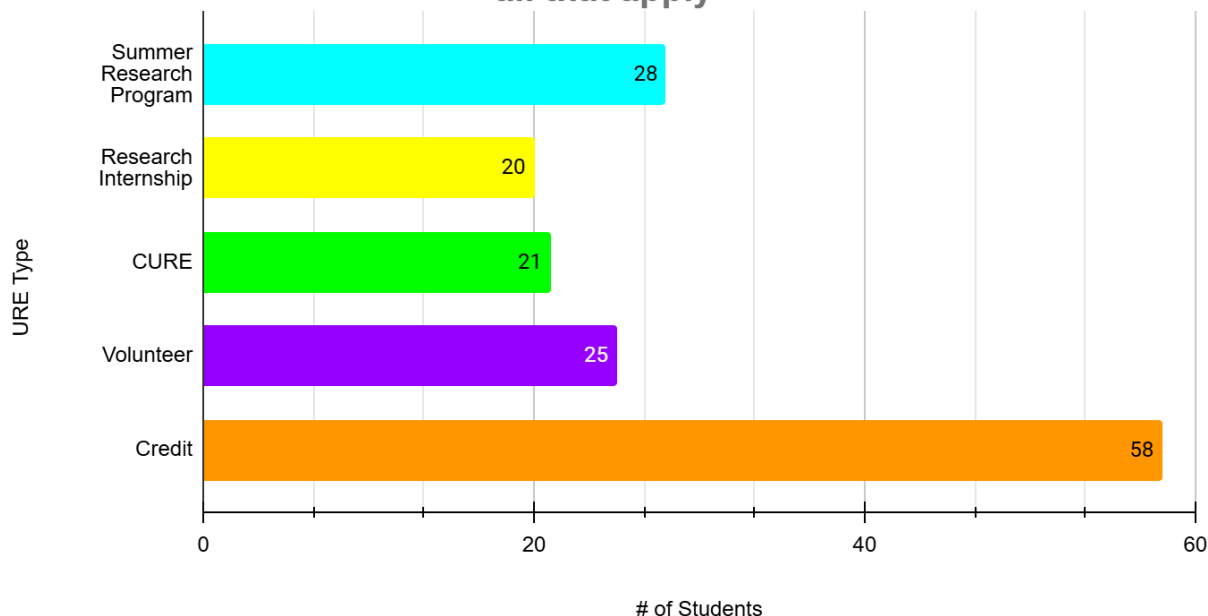


Figure 2.3: Student Responses to Survey Question 1 (Have you had or are currently in a research experience? Select all that apply)

Survey Question 1 (Figure 2.3) indicates that 77% of students in our sample are participating in research for academic credit which is also known as independent study. The remaining choices for this question were selected by a smaller range of students, but have similar levels of representation. Survey Question 2 provided students with the opportunity to contextualize and describe their research experiences in the form of an open-ended response. Most research projects that students provided in response to this item were Biology related which is unsurprising given the students we had sampled. In Survey Question 3 (Figure 2.4), we provided a range of statements that students could agree or disagree with regarding how the structure of their URE affected their engagement with research and their research mentoring.

Q.3 Indicate to what extent you agree or disagree with the following statements.

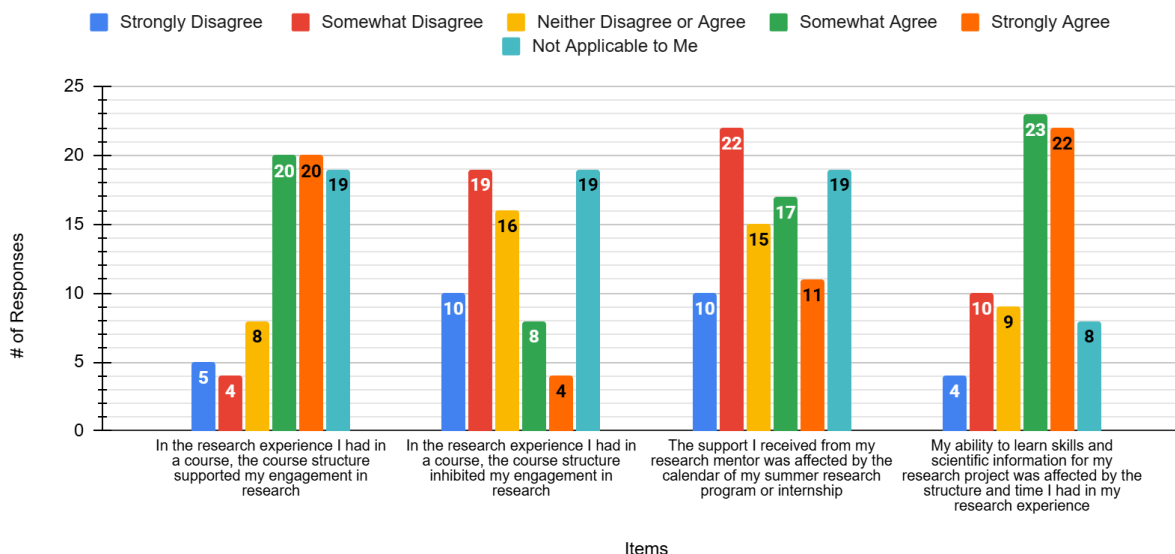


Figure 2.4: Student Responses to Survey Question 3 (Indicate to what extent you agree or disagree with the following statements)

Results for Survey Question 3 were a bit mixed. For the first and last statements, the vast majority (about 40-45 students) responded with the agree or strongly agree option. There was a mix of responses for statements 2 and 3. In addition, the first 3 statements were considered to not be applicable in the case of a subgroup of 19 students.

Mentor-Mentee Dynamics (Items 4-8)

Q.4 The individual who I identify as my primary research mentor is...

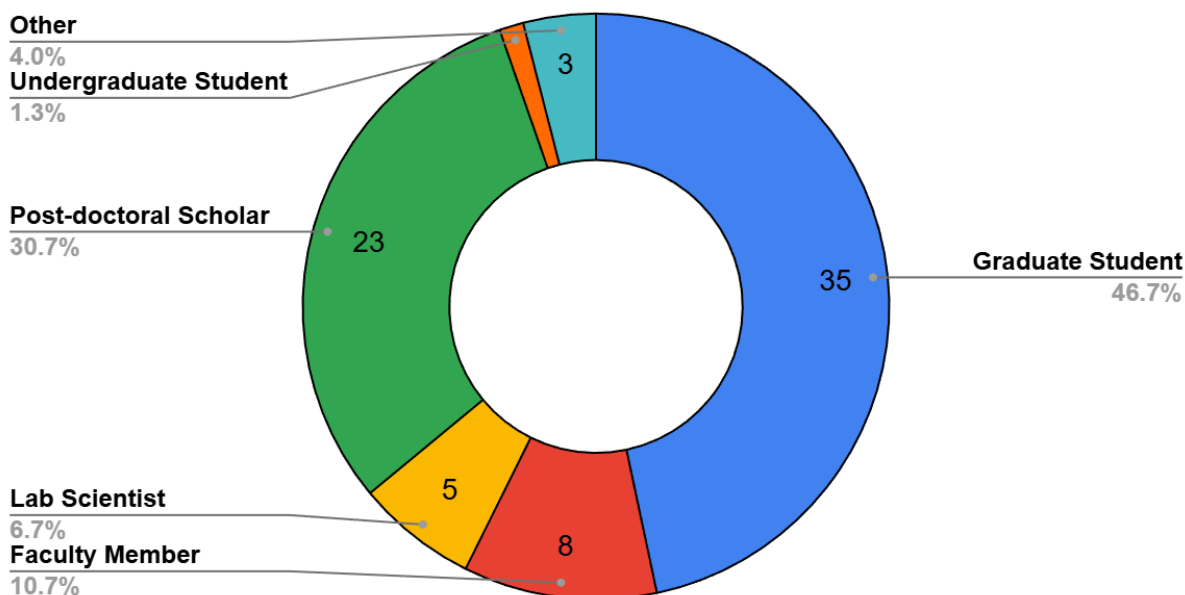


Figure 2.5: Student Responses to Survey Question 4 (The individual who I identify as my primary research mentor is...)

The *Mentor-Mentee Dynamics* factor consisted of Survey Questions 4-8. In Figure 2.5, we present the responses for Survey Question 4. Based on the research team's familiarity with UREs within the chemistry department at our institution, we expected most students to have a research mentor that was either a graduate student or post-doctoral scholar. Indeed, we see that about 47% of students have indicated that they had a graduate student mentor and that about 31% of students have indicated that they had a post-doctoral scholar mentor.

Q5. In general, how often do you interact with your primary research mentor about your research project?

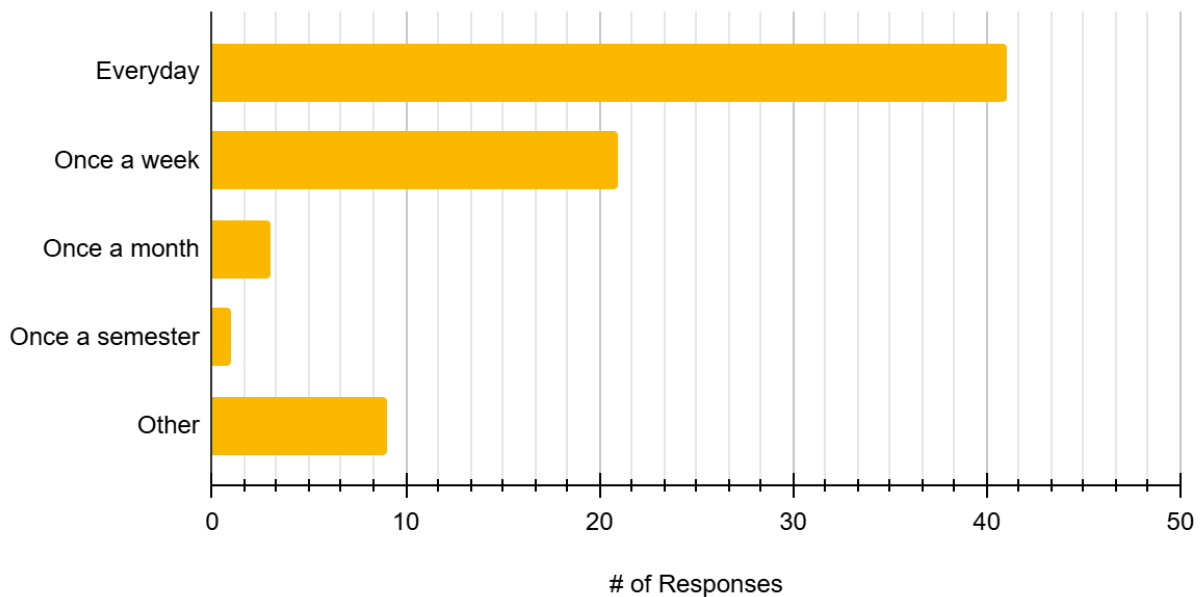


Figure 2.6: Student Responses to Survey Question 5 (In general, how often do you interact with your primary research mentor about your research project?)

Figure 2.6 is the student responses to Survey Question 5. Here, about 55% of students (41 out of 75) reported that they interact with their research mentor on a daily basis about the research projects they are engaging with. This is reasonable as most of the students in the sample have graduate student mentors who must spend a lot of time in their research labs as part of their programs. The amount of frequency for interactions between mentor and mentee implies a few things however. First, that most of the students in our sample are making time to participate in research on their own which coincides with their earlier responses in Question 1 that they participate in research in a fashion similar to independent study. Second, that undergraduate students are feeling comfortable communicating with their mentors or at the very least, have mentors that are actively engaged with what they are doing in the lab. Third, and lastly, that students are engaged with projects that they can frequently contribute which aligns with the very detailed descriptions we got of research experiences back in Question 2.

In Survey Question 6, we asked students how long they had been working with their primary research mentor. About 30 students (40%) have less than 1 semester (~5 months) of experience working with their current primary research mentor, 18 students (24%) have less than 2 semesters (~10 months) of experience working with their current primary research mentor, and about 16 students (21%) have less than 3 semesters (~15 months) of experience working with their current primary research mentor.

Q7. What is the primary method of communication with your research mentor?

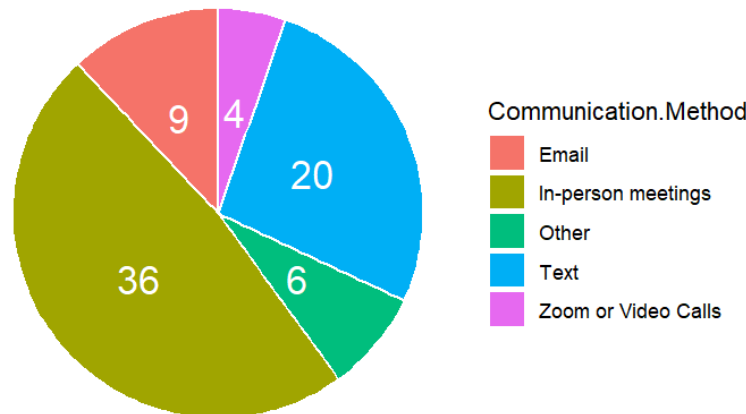


Figure 2.7: Student Responses to Survey Question 7 (What is the primary method of communication with your research mentor?)

The primary method of communication with research mentors was the focus of Survey Question 7 (Figure 2.7). The responses that we received indicated that more than half of the students communicated with their research mentors in person which aligns with our data from Questions 5 and 6. Altogether, this paints a picture that most of the students in the sample are actually working quite closely with their research mentors as opposed to being fully independent.

Q.8 Indicate to what extent you agree or disagree with the following statements about your research mentor

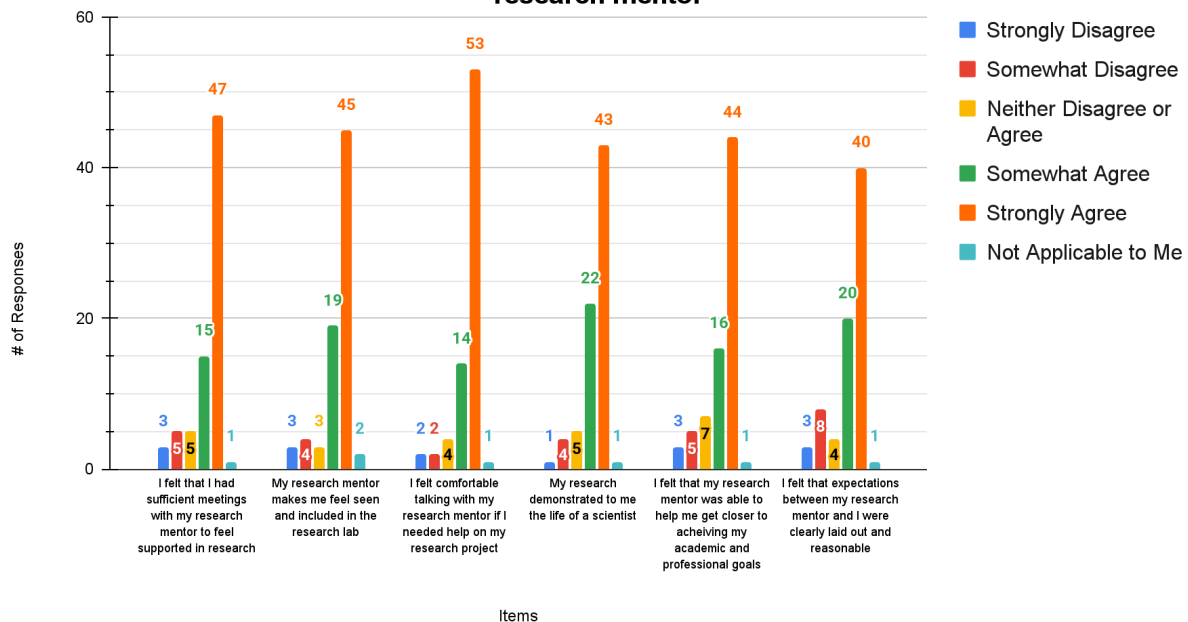


Figure 2.8: Student Responses to Survey Question 8 (Indicate to what extent you agree or disagree with the following statements about your research mentor)

The final *Mentor-Mentee Dynamics* question (Figure 2.8) contained several statements about their research mentor for students to agree or disagree with. For all statements, at least 75% of students either agreed or strongly agreed. Thus, at least for our sample, the majority of students had established a very positive working dynamic with their research mentors which is quite ideal. Given the frequency of interaction and duration of time spent working with their mentee, this also demonstrates that research mentors are doing a fine job of maintaining the positive established dynamic.

Teaching and Mentoring Practices Exposure (Items 9-18)

The *Teaching and Mentoring Practices* factor was represented through Survey Questions 9-18. We anticipated having students experience a wide range of teaching approaches and mentoring practices in research so opted to have most of these questions be open-ended in order to get detailed and specific examples of what research mentors are doing. Once we completed a review of the student responses we were able to categorize them into specific subgroups of interest.

Q.9: Please describe what actions your research mentor took to teach you scientific knowledge (e.g. facts, theories, principles) for your research project.

The first subgroup we identified for this question was from responses related to mentors who performed direct lectures for students of scientific knowledge for the research project or guided them towards sources of literature. In the above responses, research mentors took a more direct and hands on approach with getting students started with their research projects. We do note some differences in the “level of engagement” of instruction that is occurring here as only a few of these responses explicitly say that the student was an “active learner” or had agency in their own learning.

She gave me literature to read before I began researching, then explained troubleshooting and debugging methods and possible reasons that the experiments did not work.

She would show me slides at first and let me ask any questions in which she answered all of them very thoroughly and gave me additional scientific articles to read more about. While planning for experiments, she would sit down with me and let me think of what I think we needed to do and if I was wrong/stuck, she would then help me out.

My mentor would always tell me what was physically happening in a chemical reaction that I was running. I would familiarize myself with the mechanistic reasoning behind all chemical syntheses.

My research mentor gave me specific slideshows to understand more about the background of my project, and textbooks to delve more into the field. Also, if I have any questions, I just ask him and he explains it to me so I understand better.

Towards the beginning, we would have weekly journal clubs where she would “assign” a paper related to our project for me to read, and we would discuss it together a week later. She also regularly sent me procedures, scientific papers, and other supplemental papers related to the experiments we were conducting that week.

The next subgroup we identified from these responses were students who learned scientific knowledge in their research projects from a more balanced set of materials such as scientific literature, demonstrations, conversations, and research seminars. These responses are notable as they indicate that the students are actually being well-integrated into the academic ecosystem beyond just taking science courses.

Thus, these research mentors are engaging their students not just in research, but in resources that will help develop their understanding of what it takes to be a researcher.

He demonstrates laboratory techniques and directs me to good literature references. I am able to ask for help in any step and consult him on any specific reaction I'm doing. We regularly meet to discuss what I'm doing where I will be able to talk about what I'm doing and ask and answer questions about specific principles.

She was a GSI for the organic chemistry class. She advises me to go to seminars. She gives me papers to read and resources to learn reactions, and she suggests classes to take.

My mentor continues to teach me scientific knowledge in a well-rounded manner, from teaching me essential principles, industry related work, and the reality of research in the biotechnology sector; fostering a safe space where I can always ask questions; teaching me foundational lab skills; and naturally allowing me to gain excitement and understand the significance of our project.

For Survey Question 10, we had students describe research protocols and techniques that were taught by their research mentors. In this case, the main category we had was “shadowing”. This is because the general trend was that most students said that they learned important research protocols and techniques through careful observation of their mentors working on the experiments first, before they were allowed to attempt it themselves.

Q.10: Please describe what actions your research mentor took to teach protocols and techniques for your research project.

It's been a while since I've been taught a protocol/technique but as I remember it, it is me watching him do it for maybe a few of our meetings, or I watch him do it for a meeting and then for the next meeting I try doing it along with his guidance.

I was assigned online training, EH&S resources, and safety sheets. We also went through all pertinent safety guidelines and protocols in person with him demonstrating, supervising me for the first few times, and being available to help at any point if I am unsure about the exact procedure.

My mentor taught me essentially everything I know about organic chemistry research; she taught me how to use NMR instruments, how to interpret NMR spectra, how to use a glovebox, how to efficiently run a column, how to workup reactions, what to consider when trying to find good column and TLC conditions, how to flame-dry glassware, how to setup various reactions, and so much more.

Some of the higher level examples of teaching here involved students mentioning that their research mentors implemented scaffolding.

First I observed her doing the protocol, then I did the protocol under supervision, then I did the protocol without supervision, then I taught the protocol to other students.

My research mentor would invite me to observe all her experimental procedures first so that I could learn while she explained. She would provide me with a copy of the protocols, which I could follow along with, and sometimes she would provide videos to watch as well. After sufficient observation, she would allow me to attempt the protocol/technique while observing, before allowing me to do them myself.

Teaching of data analysis was asked in Survey Question 11. Here, we determined that students learned data analysis from their research mentors through several methods.

Q.11: Please describe what actions your research mentor took to teach you data analysis for your research project.

Due to the similarity between my own research project and theirs, I very much was able to emulate what they did for data analysis, and draw similar conclusions for different proteins.

She mainly gave me coding notebooks with annotations in them so I can learn about the code itself. After the graphs/data has been processed, she would walk me through them and we would think about what the data meant together.

When it came to data analysis, he tried showing prior data sheets he used, but I mainly had to figure out the stuff on my own.

I learned most data analysis techniques outside the project by taking classes. We will discuss what is the best way to present data from experiments.

Weekly meetings with the entire group have group members present their data. This helped me understand how people in the lab are expected to present their data and how to interpret it.

He had lots of different functions and libraries that the lab created which he walked me through and gave me links to their documentation. I had a good amount of background experience in data analysis and coding, so I needed less help.

Whenever we first got data, she would walk me through the data we collected to show me how she would interpret and analyze them. She would also share the figures that she created from the data so that I could get a better understanding of the visual representation. I get regular practice from reading papers and seeing their figures as well.

Q12. How did you learn to address limitations of your experimental design in research? Select all that apply

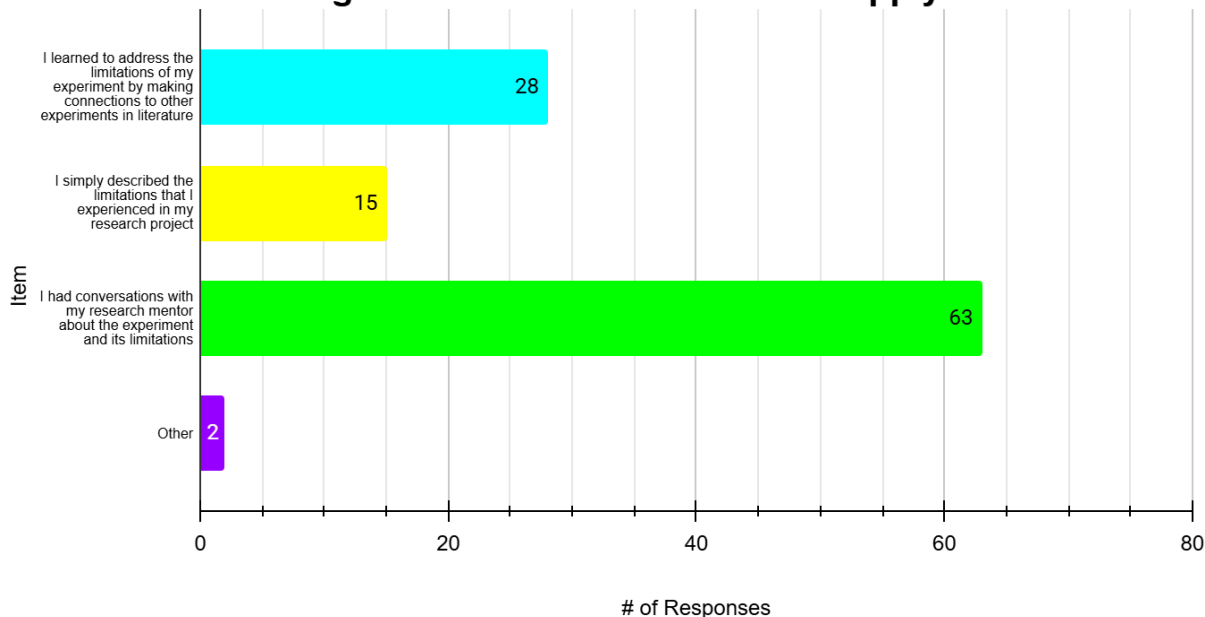


Figure 2.9: Student Responses to Survey Question 12 (How did you learn to address limitations of your experimental design in research? Select all that apply))

In Figure 2.9, we have the student responses to Survey Question 12 which asked students how they were taught to address limitations of experimental design in the research from the multiple options that were listed. 84% (63) of students said that they had conversations with their research mentor about the experiment and its limitations. 37% (28) of students said that they addressed the limitations of their experiment by making connections to other experiments in the literature. Altogether, the responses here support the notion that most of the students worked very closely with their research mentors which we established in the breakdown for the *Mentor-Mentee Dynamics* items.

The next few items were more focused on gauging how students were experiencing certain mentoring practices in research rather than instruction of research aspects. The first mentoring practice we asked about was providing guidance for proper

scientific communication as seen below in Survey Question 13 and its responses. As most of our sample was taking research on their own time, most instances of scientific communication involved preparing for lab group meeting presentations. In many cases, the mentor was heavily involved in preparing the student for these presentations by designing slides and practicing with the student.

Q.13: Please describe what actions your research mentor took to help you to communicate (poster presentations, oral presentations, lab reports, research group meetings, etc.) your research findings?

He would be available for meetings outside of our regular schedule where I can come in and ask questions. And for preparing for a group presentation we would run through practice a few times a few days before. Sometimes I would make it on my own and then show him for feedback.

My mentor has given me general guidelines for creating oral presentations and research group meetings. Then we extensively go through my presentation where I get feedback on slides, content, and ordering. I gave a mock presentation for the research group meeting to go through the delivery and slides again.

She gave me the opportunity to do a presentation to her on the background of the molecule. I did the mechanism problem during a group meeting. She also helped me begin using a lab notebook and formatting it properly.

We would have weekly lab meetings and I would talk about my individual project and even present oral presentations during these meetings to the rest of my lab members.

She has supported me with one-on-one meetings with my PI, subgroup presentations, and poster presentations by going through my slides/posters and asking me questions about things others might ask. Additionally, she has thorough feedback on my figures, layout, etc.

Next, we asked about the general depth of guidance students received from their mentors for getting started on the research project in Survey Question 14. Given the lack of homogeneity in UREs, it is not surprising to see a large variety of responses to this question. Mentors, for the most part, tried to meet the students where they were at in terms of research experience and project objectives. They filled in a more lecturer-style role with students having space to ask clarifying questions as appropriate. A few students indicated that their research mentors were able to engage them with some research scaffolding to the point where they could be seen as more “active learners” in the beginning of the project. It seems that mentors did not try to engage the students with their own goals and interests when it comes to what projects to assign. Overall, most students still felt that their research mentors were helpful.

Q.14: Please describe what actions your research mentor took to guide/support you at the beginning of the research project.

He gave me literature to read in advance to get me caught up to speed and started very broadly with the purpose and goal of the project to make sure I understand the conceptual reasoning for what we are doing. He would also ask questions as an opportunity for me to voice any confusions I had.

He was very kind when guiding me through the concepts, gave me a presentation on his specific research, and demonstrated the glovebox techniques I needed. I was also given a literature procedure that he had experience with to attempt myself and check to see if I was able to satisfactorily replicate it.

Give me physical protocols, advice from past researchers in her lab, always available to discuss possible projects and also concepts via SLACK or in-person meetings.

They were very much a teacher and a mentor, as I had to quickly learn many different aspects of the job. They taught me essentially everything about working in a lab, save for some very basic lab skills.

She was just very welcoming to all the questions I had at the beginning of the research project and provided me with a lot of literature to better understand why things were set up the way they were.

I actually didn't have as much support as I was initially taken on as just a summer intern. I took a short week-long bootcamp on cloning and basic biology lab techniques and then just learned as I went along.

She provided guidance on what types of projects would be feasible for me to complete as an undergraduate student in the lab. Having observed her main project and being familiar with the content, I was able to formulate my own related research project idea.

At the start, my mentor would go through the whole day with me and offer me guidance through any steps of an experiment. She started off by having me make the components of the main experiment first and then progressed which allowed me to get a better grasp of the concepts since we essentially started from nothing..

Student responses for Survey Question 15 painted a clearer picture on how research mentors were setting expectations to their research mentees. Expectations were set for what type of communication to have, for the specific tasks the undergraduate student would be working on, and for how much time the student should be spending in the research lab. The expectations that were set were very much centered around the mentee. In fairness, while it is true that the question phrasing was leaning towards this direction, it is significant to note that there was no mention of students mutually setting two-way expectations for their research mentor. Another interesting tidbit is that research expectations that were described in the responses were more segmented, or focused on a very specific part of the project. There were little to no expectations set on the “bigger picture” or long term directions of the research project.

Q.15: Please describe what actions your research mentor took to set expectations for the research project.

My research mentor communicated how many hours she wants me to be in the lab to make adequate progress towards the project.

She first went through the data they had already collected and laid out the timeline with things that must be done before the publication process. There was also a to-do list that was updated every day for the whole team so we were all updated with what needed to be done.

My mentor laid out in my initial interview that the responsibilities would eventually become expected of solely myself. I understood that after she had sufficiently instructed me, I was responsible for running reactions and doing lab work on my own..

Very thorough in the beginning. Asks me lots of questions to see if I am understanding, lets me ask lots of questions, gives me tons of resources (literature, videos, tutoring, etc.)

Before beginning, she had me plan out all the steps and processes I would have to complete to collect all the data I would need from start to finish. This helped me be able to estimate how long each step would take, and plan out an overall timeline for myself. She would check in with me every week to create a weekly plan that allowed us to stay on track for the research project.

Providing feedback to undergraduate mentees is a key component for any type of research mentoring. The responses to Survey Question 16, which was asking about how students received feedback from research mentors. The most common scenario for receiving feedback was during research check-ins or when a research deliverable was completed. Students indicate that mentor feedback is helpful and a positive experience. A few mentors went above and beyond for their undergraduate mentees by pairing feedback with reassurances to the student's ability or emphasizing their growth or promoting their self-efficacy in some way.

Q.16: Please describe how your research mentor provided you feedback on your research work.

We would meet for a short amount of time to talk about the progress of the project and if we were following the timeline and if anything needed to be adjusted.

Checks in with me every so often while I'm performing experiments to see how things are proceeding and provides feedback when necessary, checks in with me at the end of each reaction to see how successful it was and next steps to proceed with.

I work side by side with my mentor on our project, and she often give me pointers on how to be more efficient, guidance on how a reaction is progressing, and is always open to questions and help me with anything

She would acknowledge my work and give me critiques when necessary. She would also pitch in her own ideas I could try out when I bump into a wall for my research.

Most of the time, she would give feedback directly when I show her in person; however, she would also leave comments on my docs/slides once I share them with her. She would also encourage multiple drafts and continue to leave feedback until we were both satisfied.

My mentor has always given feedback and constructive criticism if I ever do something the wrong way or have less-than-desireable results.

My mentor cheers me on whenever I achieve a result we would have liked and if something goes wrong she says she trusts my work and to complete the experiment again to see if the results differ. If I go through a protocol and do something wrong she says that she usually does it a different way but it's alright to make mistakes.

Based on the student responses to Survey Question 17, students felt comfortable with the pace at which they developed independence on their research projects. Typically, these students reached the point where they could be a little more independent on their research projects when their mentors felt that they received adequate enough research training. A few students said that they were allowed to have active input or contribution to the future direction of their research projects.

Q17. How did your research mentor foster your independence during the research project if at all?

My mentor constantly asks me what experiments I would like to perform and if there is a route with the experiment that I would prefer to take. She checks in with me constantly to see if I want to pivot to anything else and allows me to conduct my own experiments to characterize our components.

My research mentor often asks me to do things on my own (now that I'm trained up), which builds independence. This includes setting up reactions, researching reactions, getting chemicals, purifying reactions, working up reactions, and analyzing products via NMR on my own.

After I was trained, I began drafting a daily schedule for myself. This schedule was then reviewed and tweaked where needed by my mentor. This way, I was able to do the research while still having oversight on my performance.

I think she fostered my independence by doing things with me for the first time. After that, she let me do it on my own, but was still always by my side to watch me and answer any questions or correct me if I was doing something wrong. Additionally, she would let me think of hypotheses/controls/edits to the experiments first before letting me know her own thoughts.

I gained more and more independence as I gained experience. Initially, I was mostly just doing tasks under his experiment. Then, I was able to work on another of his experiments independently. Now, I am doing my own experiment and have independence over the experimental design.

Over time, after knowing that I can complete a procedure on my own, she will allow me to do so on my own at a time and make my own lab schedule. In the beginning, she would send reminders on what to do, and I would also ask more questions. I have become more comfortable in conducting my own project now, and am confident in completing things independently.

Q.18 Please indicate to what extent you agree or disagree with the following statements

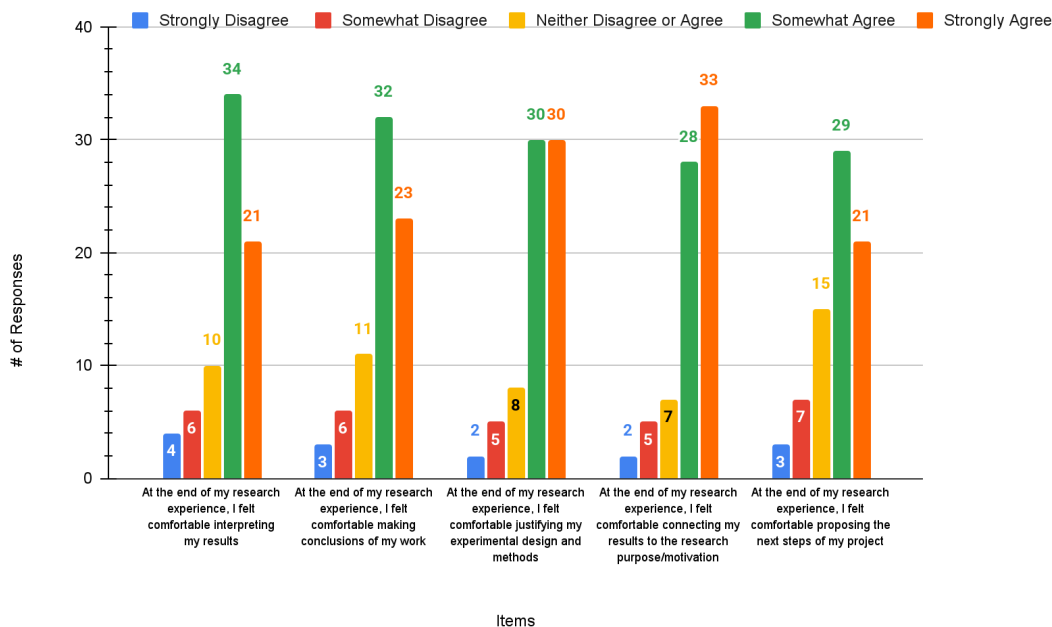


Figure 2.10: Student Responses to Survey Question 18 (Please indicate to what extent you agree or disagree with the following statements)

Survey Question 18 was the last question in the survey for the *Teaching & Mentoring Practices Exposure* factor. Students were provided a list of statements about their comfort with certain research aspects which they could agree or disagree with. According to the responses (Figure 2.10), we report that between 67% and 80% of students either agree or strongly agree with all of the listed statements. It is clear that students believed that their research mentors were quite helpful to them as they engaged in research and had a positive influence on them. Not only is this consistent with our positive-leaning results we have already discussed for the earlier survey questions, but provides evidence that research mentors are involved with their students throughout the entire process of doing research.

Research Motivations (Items 19-21)

The *Research Motivations* factor was represented through Survey Questions 19-21. We focused on what the motivations were for students to start participating in research and whether those changed over time. In Figure 2.11, we showcase the results for initial student motivations for research.

**Q.19: Why did you initially look for a research experience?
Select all that apply.**

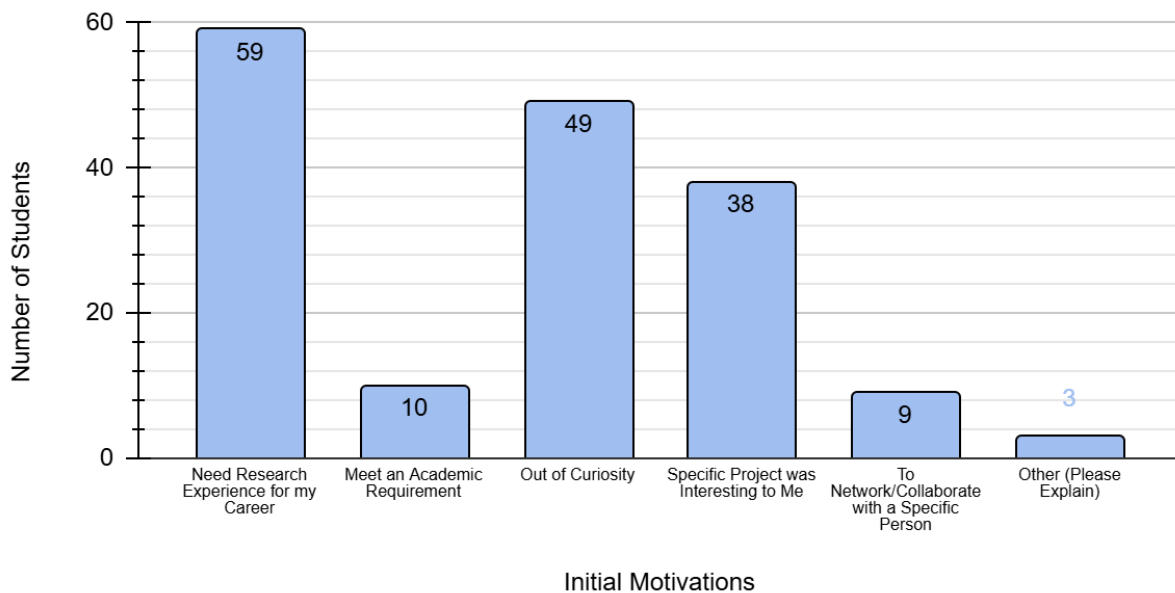


Figure 2.11: Student Responses to Survey Question 19 (Why did you initially look for a research experience? Select all that apply.)

65-80% of students initially started research for personal reasons such as advancing their career prospects and learning more about what interests them. This result shows that the students in our sample are demonstrating quite a bit of agency when it comes to how they engage in research. Based on the responses we received from Question 2, where they described their research projects to us, it appears that many students already had an understanding of what their research interests were and pursued them accordingly. The students demonstrating their agency are further supported by the fact that the majority of them are doing research for academic credit / on their own time according to our results in the *URE Structure* survey section.

Q20. What were your primary goals when you first started your research experience? Select all that apply.

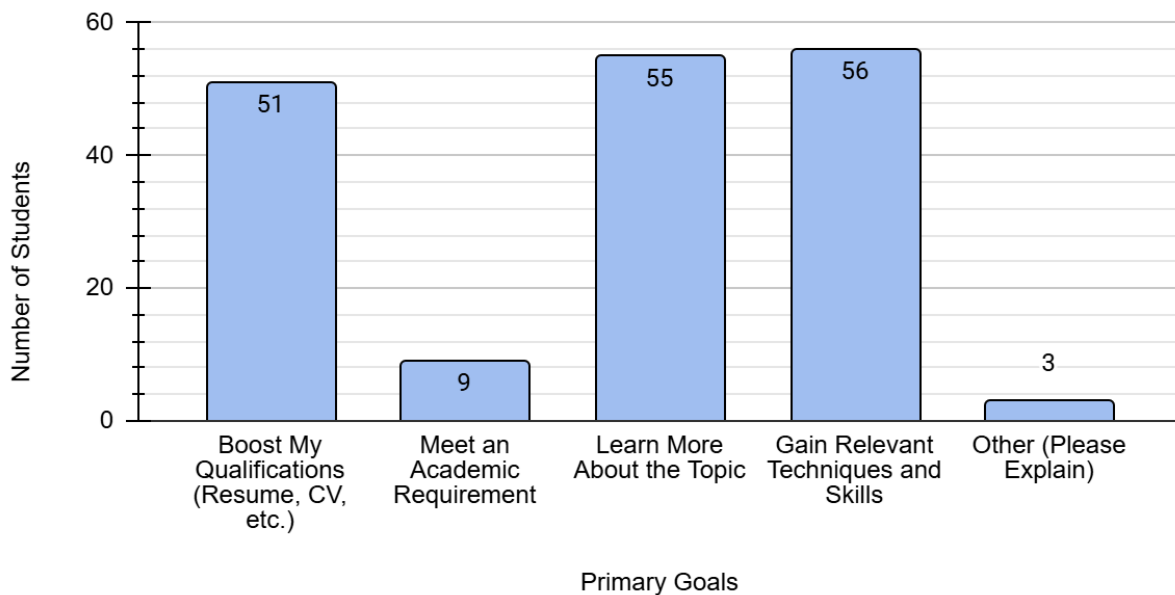


Figure 2.12: Student Responses to Survey Question 20 (What were your primary goals when you first started your research experience? Select all that apply.)

Building on from Survey Question 20, Survey Question 21 then asked students to share about specific primary goals they might have formulated as they began doing research (Figure 2.12). There does not appear to be much of a disconnect between the students' internal initial motivation and achievable goals they set for themselves in the research since the responses are more favored towards personal passions and personal development. However, the students grew to value the importance of learning and mastering relevant techniques for their research projects.

Q21. Now that you have/had your research experience, has it fulfilled your initial motivation for research or changed it?

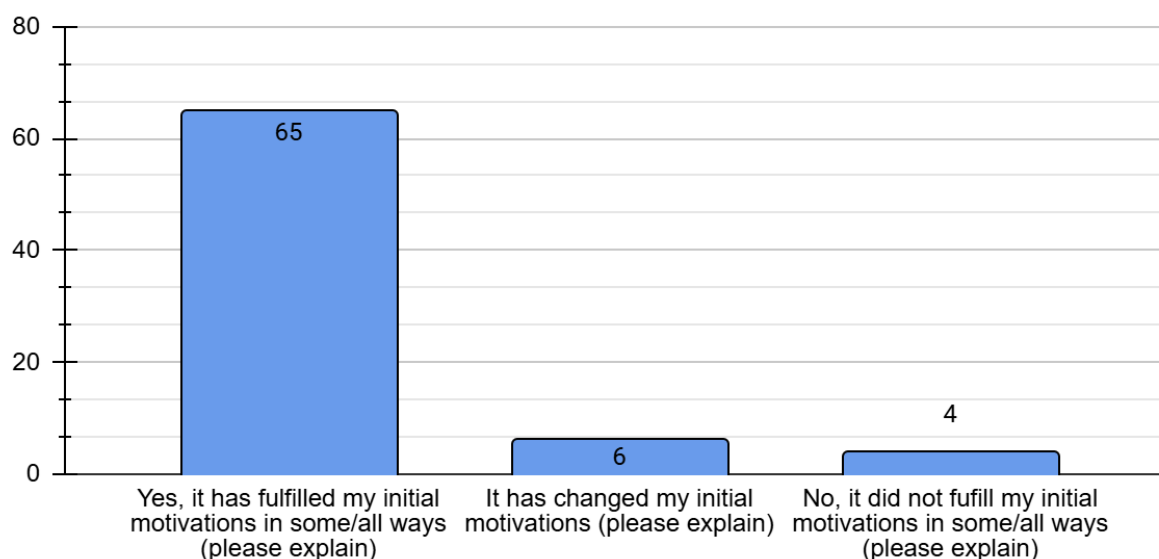


Figure 2.13: Student Responses to Survey Question 21 (Now that you have/had your research experience, has it fulfilled your initial motivation for research or changed it?)

To conclude this section of the survey, Survey Question 21 asked students whether participating in research fulfilled the initial motivation for participating in research or if the motivation changed during the URE (Figure 2.13). A super majority of students simply reported that their initial motivations for research were fulfilled and that they had not fully realized any additional motivations or goals. This result is reasonable as more than half of the sample have less than 2 semesters of research experience so it's plausible that they hadn't had enough time to further reflect or change on this matter.

Student STEM Identity & STEM Confidence (Items 22-27 | 34-39)

The *Student STEM Identity & STEM Confidence* factor was split into two question groups on the survey (Questions 22-26 and Questions 34-39). In these sections of the survey, we hoped to learn more about how student's level of STEM self-efficacy, their confidence, and their scientific identity would influence how they engaged with both their research mentors and their research projects. We opened the first question group by asking students if their research mentors ever introduce them to diverse role models in their field of study (Survey Question 22). From this, we determined that unfortunately 71% (53) students didn't have any introduction to diverse role models in research.

Following this, we asked students if their mentors had ever challenged any stereotypes that they might have had about doing research or being a scientist (Survey Question 23). While a third of the students replied that this question did not apply to

their experiences, we received insightful accounts from the rest of the sample with a few interesting examples listed below. The trend here is that students are learning from their research mentors what it is actually like to live as a graduate student, what the expectations are, and what kind of people are in academia. Most undergraduate students in the study assumed that graduate students were exemplary when it comes to being studious and talented in their fields, but are pleasantly surprised that they are normal humans too with normal lives and flaws. The students were able to understand that just like themselves, many of their research mentors were also learning and developing into a scientist.

Q.23: Please describe any ways in which your mentor(s) challenged any stereotypes that you had about research or researchers.

My mentor was telling me that when he was an undergrad his scores weren't the highest by any means which was reassuring because I learned that research wasn't about how smart you were but more about not giving up and trying your best. Additionally I learned that research doesn't have to be hierarchical. In our meetings he makes it clear that we don't have to go along with what he thinks and are free to disagree or have opposing thoughts.

My mentors were both women in STEM and one of them was of color. They have been open about the external struggles they have faced as a person of color in STEM. This is why we create a space to enforce a positive mindset within students so that they can tackle the outside STEM community with confidence.

I thought lab PIs usually didn't involve themselves in the nitty gritty daily work of maintenance of the lab, and was mostly concerned with the research aspect, but Dr. [REDACTED] was highly involved in both.

She was a female graduate student. She actively asked questions and gave valuable insight during each meeting. This inspires me and reduces my fear/intimidation of a male-dominated field.

She was a woman who had her own lab and also had many diverse people as a part of it! She was strong and educated, but was not harsh. She helped me learn a lot without it being a competitive environment.

I thought researchers all took their research very intensely and didn't have a good work-life balance, but my research mentor showed me that it was possible to manage the workload. Additionally, I thought all researchers knew exactly what they were doing, but I realized that it is a learning experience for everyone and not everything always works on the first try.

There is a common stereotype that researchers do nothing but work and are cold-hearted and while there were many hard-working individuals in the lab, everyone is very kind, especially to beginners and people who did not have prior lab experience.

Students got more personal in Survey Question 24. We received a lot of student specific examples for research mentors who made them feel included in the research lab. Some more intricate and highly involved levels of inclusion were included in the list below. The general sentiment in the remaining responses was that students felt seen or included through basic socialization, lab events, or lab meetings. Throughout the responses, students noted that they self-aware that research mentoring with inclusivity would take time and would look different from student to student.

Q.24: How did your research mentor make you feel included in the lab, if at all?

Mainly just small talk and kind of introducing me to the other grad students in the lab which opens up more small talk. Eventually I know them well enough and they know me well enough where I feel like I am included and seen.

We share bits of our personal life at the beginning of group meetings. We also have small talks in the lab frequently and I feel that people are very concerned about my wellbeing and how my expectation of the lab is fulfilled.

He helped me feel included in lab meetings and invited me to lab gatherings. I only felt truly part of the community when other undergraduates joined and there was a strong undergrad community as well, though.

My research mentor invites me to everything she can, if something is messaged in the SLACK about hanging out she checks with me if I am going. When I started out she asked if I would be interested in joining their baseball team and joining them on the lab trip even though I hadn't officially started yet.

He would always bring me everywhere and we would always have lunch together to discuss options. He would have things for me to do and introduce me to other researchers and then those researchers would gladly take my questions as they discuss what they are working on.

The next two survey questions, 25 and 26, asked students about the frequency of their research mentor sharing personal stories of adversity and if they ever felt that their research mentors interacted with them differently due to any of their identities, respectively. In the case of both questions, almost all students replied that they had not encountered either of these scenarios in a significant way in their research experiences.

As we are aware that not all interactions between the mentor and mentee occur in a research context or the research lab itself, we wanted to learn more about these more outside or extraneous interactions that may have contributed to the development of students' STEM self-efficacy in any meaningful way. The data for Survey Question 27 indicates that connections between research mentors and their mentees is mostly done during small moments while working on the research project. In these moments, mentors and mentees connect over their personal backgrounds or through shared interests.

Q.27: In what ways, if any, has your mentor connected with you beyond formal professional settings to understand your background, experiences, or skills?

My mentor finds time for us to chat about things other than research and work. For example, they are constantly asking to know more about my upbringing and encouraged me to present what it means to be a Latino in Chemistry at Cal.

We would make jokes here and there as well as learn from other things outside the lab. I would tell him more about the medical school process and life in the bay area for example.

We would sometimes have short conversations while she pops into the lab and I happened to be there working, and we would make some small talk sometime, so she knows I want to go to vet school.

We have gotten dinner together or have gone on breaks in between experiments where we talk and go on walks. We talk about our previous research experiences, classes, and life in general, and I learn a lot about his experiences in undergrad that shaped him into the grad student he is today.

He has always tried to tailor my work to being as close to what I want to do as possible. I was initially interested in synthetic chemistry, and the closest thing to that in my work was cloning and designing constructs. Later on, I gained an interest in computational work. He came up with an idea to utilize computational chemistry and helped teach me to use the microscope to do more dry lab work.

My mentor has always been open to chatting casually about my background and interests, which made me feel more connected. For example, they asked about my time in the military and how it shaped my work ethic while tying that to lab projects. It felt like they valued my unique experiences beyond just research.

For Survey Question 34, which was about how often research mentors acknowledged the work of their students, we found that over 90% of students indicated they felt acknowledged. 80% of students responded that they felt included in their research groups beyond working in the research lab itself such as during research meetings and group social gatherings (Survey Question 35). 70% of students felt comfortable connecting with other lab members besides their research mentor and that they felt they fit in as a member of the research group (Survey Question 36).

Discussions about personal background and life experiences came up naturally between research mentors and mentees based on the responses to Survey Question

37. For some students, they were able to learn more about the journey that their research mentors took to arrive at their current occupation in short conversations or more dedicated conversations if the mentee felt comfortable enough to ask. This aligns well with the notion that students in our sample are well-included in the research environment.

Q.37: How did your mentor, if at all, give time for you to learn about their background and story?

Many were very open about talking about their experience if asked. Or if one had questions about life after college, many would jump in to offer advice.

It was a bit sporadic but I learned about my mentor through a collection of shorter conversations at the end of the lab day.

She would just give short accounts about her background/experience, but if I ever asked her in detail, she would always answer.

Proactive steps that research mentors took to be respectful of their students' identities and backgrounds were quite varied. (Survey Question 38). For example, some research mentors took time to directly ask their mentees about their pronouns and name pronunciations. Other research mentors created materials (such as forms and website pages) to track this information. To complement these approaches, research mentors also made sure to be thoughtful and ask questions to the students about their backgrounds and identities when appropriate.

Q.38: What steps did your research mentor take to be respectful of your identity (culture, pronouns, name pronunciation) if applicable?

Always asked questions about my background! Especially if we could relate to certain cultural backgrounds.

She treats me with respect; identity doesn't really come up in our conversations because both of us care more about becoming better scientists.

My research mentor had everyone fill out their information on a google document and referred to it to answer any questions that she had about people's identity and pronoun preferences.

He just is respectful about my culture if I say anything about it, and he respects my pronouns and asked me how I pronounce my name when I first started.

She clarified my name when we initially met. Pronouns are listed on our group website so I was able to send in my information so the lab knows what to refer to me as. She always asks questions if there is something she does not know and embraces new concepts from my culture.

This section of the survey concluded with Survey Question 39. Here, students were asked to share if they felt more confident in being a scientist after participating in research. We received a lot of insightful responses from the students. For the most part, students agreed that they felt more confident in being a scientist post research. They attributed this to just being more aware of what research is like and what it entails to be a graduate student that does research. In addition, students felt more comfortable engaging in science, applying skills and techniques that they learned in their science courses and communicating science to the general public. Participating in research helped students feel more prepared for their long-term academic and career trajectories and aligned well with the academic goals and motivations.

Q.39: After participating in research, do you feel more confident in being a scientist? If so, why?

Yes, I feel like I understand the thought process of research more and how discussion with a group opens up the doors to ideas that I wouldn't be able to generate on my own. Additionally I feel more confident speaking up to voice a disagreement even when it's towards someone with a higher standing (grad student, professor, etc) than me.

Yes! The people I work with are so kind, extremely supportive, helpful, and make the scientific community warming and inviting. I would like to work full time in a lab with people like them.

Yes, I think I have a better idea of how being a research scientist works on a daily basis and feel more confident about performing research.

Yes, I feel like I have some experience in running trials and experiments and documenting everything for later analysis, and this methodological trait is useful to have as a scientist.

Yes! I was able to learn the techniques needed to perform experiments and am now able to feel confident in asking questions and coming up with my own hypotheses/conclusions.

I feel more confident in my abilities. I've seen what it really takes and how to collaborate with others in the group. Additionally, the technical knowledge I've gained is unparalleled compared to classwork.

Yes. I am learning valuable techniques that I can apply in my future. I am also learning the process of real research and the ebbs and flows that go with it. I believe I am getting better at overcoming surprise obstacles now.

Yes, even though it's been a complicated experience I feel more confident now that I've started to be able to contribute more. Getting to see results that I contributed to getting makes me feel more like a scientist because to me, it's about the work rather than the identity.

Both yes and no. I've learned great organization skills, critical problem solving, and techniques in chemistry. However, it has made me question if a research career is right for me, and more specifically if I will be ready for graduate school immediately after my undergrad.

Student Past and Lived Experiences (Items 28-33)

The Student *Past and Lived Experiences* factor was the subject of questions 28-33 on the survey. These questions were designed to see if we could make connections between the past and lived experiences of students and how they engaged with UREs. We also were interested to see if these experiences were influencing or further contextualizing the responses that we received in the other survey factors. Survey Question 28 allowed students to describe how aspects of their personal experiences and cultural background enhanced a student's URE. We received many unique responses for this question so we opted to organize the data under a few general trends that we noticed.

First, students developed some soft skills in some of their past and lived experiences that were convenient for scientific research. These include communication of research feedback and expectations to their research mentors. Second, some students gained skills and knowledge from prior professions or academic endeavors that they could directly apply to their research work such as organization of work spaces, experimental design, and some fundamental STEM content knowledge. Third, students that had scientists or STEM role models in their families learned valuable insights that prepared them for what research is actually like. Lastly, there was about a third of our sample that felt that their past and lived experiences didn't factor much into their UREs. On a more holistic level, it is apparent that past and lived experiences affected how students need to be taught and mentored in UREs and their starting STEM identities and self-efficacies. It would appear that if a student pulled from their past and

lived experiences during their URE, they didn't do so very often. Survey Question 29 asked students to share how often they pulled from their past and lived experiences during the URE and only 15% said they did so frequently and only 20% said they did so some of the time. Everyone in the sample either did not pull from their past and lived experiences at all or only on a few occasions.

Q.28 How have you drawn upon your personal experiences, cultural background, or skills learned outside of school to enhance your research experience? What aspects of your background do you feel have been particularly valuable?

From my sports background I think I have learned more soft skills such as framing feedback as a way to improve and not to criticize. I try to be careful about how I give my opinion to make sure that there is no ill will and in turn communicate that I am trying to do my best to make the project come along well.

I worked as a barista for a couple years and I think the attention to detail and maintenance of work space skills I learned have come to be very useful in maintaining a good work ethic and lab environment.

My dad is an electrician and I used some electrical skills I learned from him during the lab. We had to wire fans.

I have been involved in CAD model design for my past work experience and have implemented this into my research.

I think my bilingual background helps me a lot. There are many international students in our lab and it helps me to communicate.

My background as a previous pre-med student has added a new aspect of curiosity that continues to fuel my research experience. I love learning about and working towards creating new medicines.

I worked in a lab in high school where I learned a lot of skills that can be directly applied into the lab, and also how to present my work and write papers/presentations/posters, and that has been very helpful. I am also very organized and that has helped me organize experiment schedules and spreadsheets for my current project.

My personal experiences taught me time management and adaptability, which are crucial for research. I've also used my background in mentoring through MESA to collaborate and share ideas more effectively in the lab. These experiences helped me bring a practical, problem-solving mindset to projects.

Past experience working as a housecleaner, I have previous experience working with particular chemicals and how to properly dispose of and clean certain things. I also have experience volunteering and shadowing in medical environments, so I have past experience learning from demonstrations and hands on.

We were interested in seeing what the reverse trend would look like, or more specifically, how participation in UREs would further build upon or transform the skills, experiences, or knowledge from their past and lived experiences (Survey Question 30). Most students (65/75) either said that this was not applicable to them or that they did not build on anything from their past and lived experience from participating in undergraduate research experiences. The few that did provide a response to this question mentioned that doing research helped them further connect with their communities or gave them new opportunities to translate their enhanced skills.

Q.30: In what ways has your research experience allowed you to build on or apply your skills, experiences, or knowledge gained from your past experiences, cultural background, family, or community?

I subscribe to science news in different languages, which often have a different focus from English science news because they are edited by people from different educational backgrounds. This allows me to find more interesting research done by people in another country.

Thanks to my past experiences with my family, I was able to find ways to connect with people of different backgrounds. I was also able to use my organic chemistry knowledge to try and understand biological mechanisms to my best extent (given I haven't taken a biochemistry class).

My research has been a great way to apply my skills, like organization from the military and collaboration from mentoring. These helped me approach experiments methodically and work well with my team. It's rewarding to see how personal strengths can enhance scientific work.

It is possible that students may have experienced some challenges with using their past and lived experiences in research or that they may have wanted to have a specific aspect of their past and lived experiences be more recognized or utilized in their UREs. In Survey Questions 31 and 32, students were asked to further elaborate these possibilities, respectively. For both questions though, every student either did not respond or mentioned that these scenarios were not applicable to them. Therefore, we report that students did not have difficulties translating specific aspects of their past and lived experiences to research and had no lingering need to have their experiences further recognized/utilized in the research lab.

Survey Question 33 served as the ending for the *Past and Lived Experiences* section. This question was included to learn from the students how their research mentors could make better use of their mentee's backgrounds and experience when doing research. We obtained several thoughtful responses from the students that help to further contextualize how students view their dynamic with their research mentors and how they perceive the mentoring they received from those research mentors. In one case, a student described enjoying getting to hear new ideas and perspectives from their peers. A sub group of students suggested that they would have liked their research mentors to be more aware of their backgrounds when considering what to have them do during the URE and be accommodating if necessary. Another sub group of students recommended more engagement between mentors and mentees on their backgrounds as it would promote more inclusivity in the research lab and thus, lead to a more healthier, a more innovative, and a more productive lab environment. It is also worth mentioning that there were a few responses where a student felt that the premise of this question was not necessary for them or in general when it comes to effective research mentoring.

Q.33: How do you think research mentors could make better use of students' different backgrounds and experiences when working on projects together?

I don't have the perspective of a research mentor, but at the very least I notice that just having more people at the table leads to the increased chance of me hearing an idea that I haven't heard before. So I think definitely opening the floor often to thoughts is good.

I think they are doing a great job at bringing in the relevance of each person's tools, but I think we can pass this down to the students. This way we can show them that their skills and experience can be valuable in STEM.

I don't really see much value in mentors utilizing students' different cultural backgrounds and experiences--in my eyes, being able to be a part of a research project is a gift from the mentor to the student, and is primarily for research purposes and is a strictly academic mentor-mentee relationship.

Generally, mentors can work to better understand a student's cultural background and the languages that they speak. Then, they can use these student's knowledge about languages to translate their research to make it more applicable.

I think sometimes international students have a worse time understanding scientific terms because they learned it in another language. This can be addressed by giving more images or diagrams to describe this term rather than describing it only in words without a context.

Making it a safe environment to bring identity into research means that people should not be penalized upon sharing more about themselves.

Research mentors can leverage students' diverse backgrounds by first understanding their unique skills, experiences, and goals through open discussions or surveys. They can then tailor tasks to align with individual strengths while encouraging collaboration that values different perspectives. Creating an inclusive environment where all ideas are welcomed fosters innovation and allows students to feel empowered to contribute meaningfully to the project. This approach not only enhances research outcomes but also supports students' personal and professional growth.

Mentors could encourage more open conversations about personal experiences and how they connect to research. It would help highlight skills or perspectives students might not realize are valuable. Tailoring roles to those strengths would make teams more effective.

By recognizing and valuing the diversity students bring to research, mentors can create a dynamic and enriching environment that benefits both students and the project. This approach not only fosters innovation but also helps students feel more connected, motivated, and invested in their work.

I really liked how my mentor was able to tailor the work I was doing to my interests. I understand that this isn't possible everywhere, but there's always so much work that needs to be done that there's usually at least something which students will find enjoyable to them.

Integration into Academia (40-44)

The *Integration into Academia* category was the last factor and section we developed for our survey instrument. It consisted of questions 40-44. In UREs, students are often exposed to new and/or complementary opportunities for their academic and professional development. We were interested to see what kinds of opportunities that students were exposed to as a result of their research participation and how that would potentially factor into their research motivations or their STEM identities. In Figure 2.14, we provide the results for Survey Question 40.

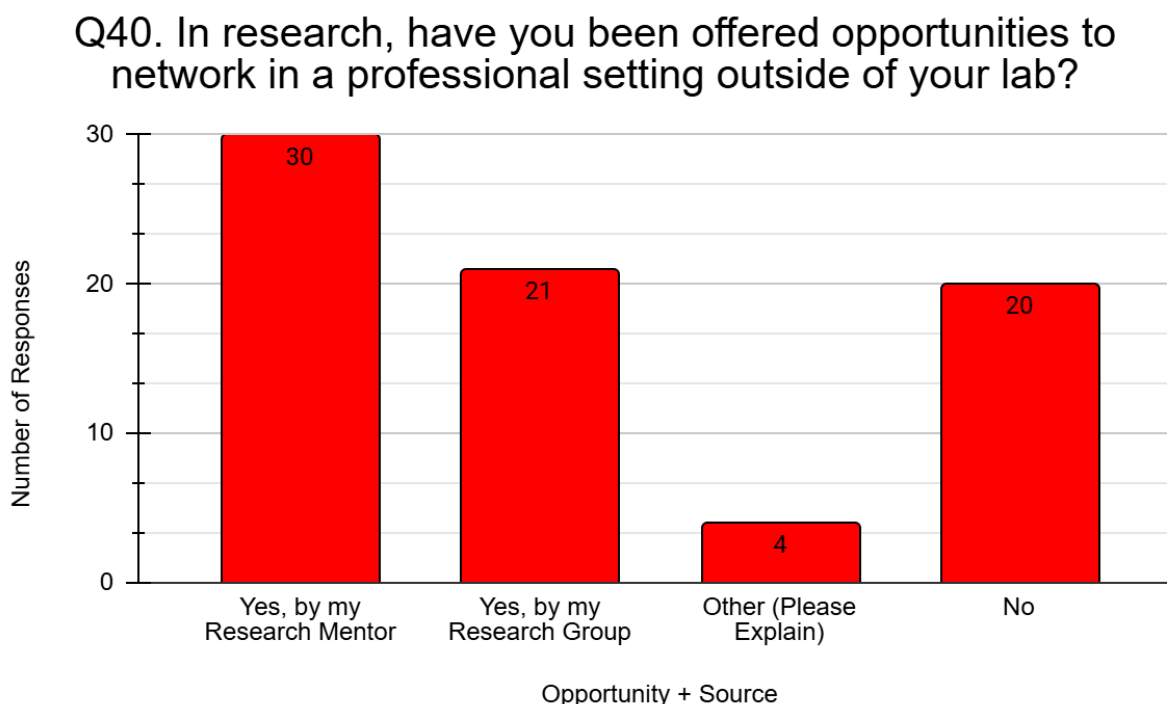


Figure 2.14: Student Responses to Survey Question 40 (In research, have you been offered opportunities to network in a professional setting outside of your lab?)

At least 60% (45) of students confirmed that participating in research provided them with opportunities to further network in academia outside of the research lab. About 30 of those students said that these opportunities came directly from their research mentors. In a follow up question (Survey Question 41), students indicated that they were able to engage more with research seminars, guest lectures, and academic conferences the most out of the given options. Figure 2.15 contains the response breakdown for this question.

Q41. If so, what were some opportunities you were provided with?

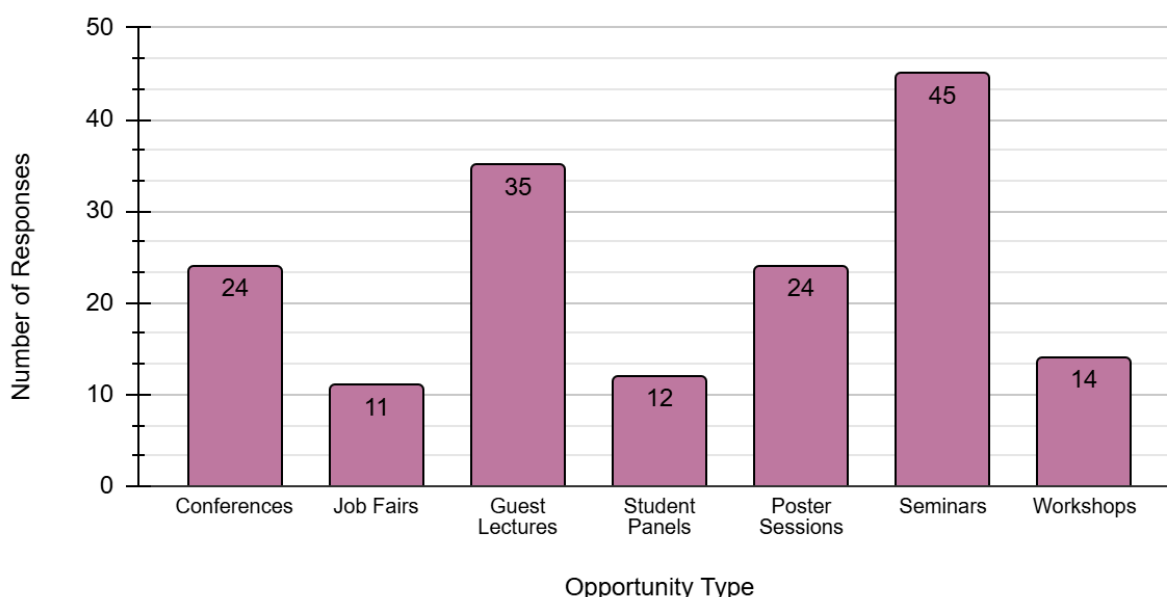


Figure 2.15: Student Responses to Survey Question 41 (If so, what were some opportunities you were provided with?)

The next question surveyed students on the extent to which they were able to engage with the opportunities that they were exposed to. The results for Survey Question 42 indicated that about 60% of students were able to actually participate in the opportunities they found out about in research. For those that didn't, students could respond to Survey Question 43 about why they did not. In these cases, students did not participate in a new opportunity if they had a time conflict or their schedules were too busy (61% and 44% respectively for this subgroup).

The final question for the *Integration into Academia* factor and thus, the final scored question of the survey itself, asked students to agree or disagree with a list of statements regarding participating in new, research-related opportunities and their professional, personal, and academic development (Figure 2.16). Students strongly resonated with the statement that they were able to grow their scientific networks. In general, the trend for each of the statements is that a higher number of students agreed

with or felt that a statement was not applicable to them, than they disagreed with the statements.

Q44. If you had at least one of these opportunities, rate your level of agreement with the following statements:

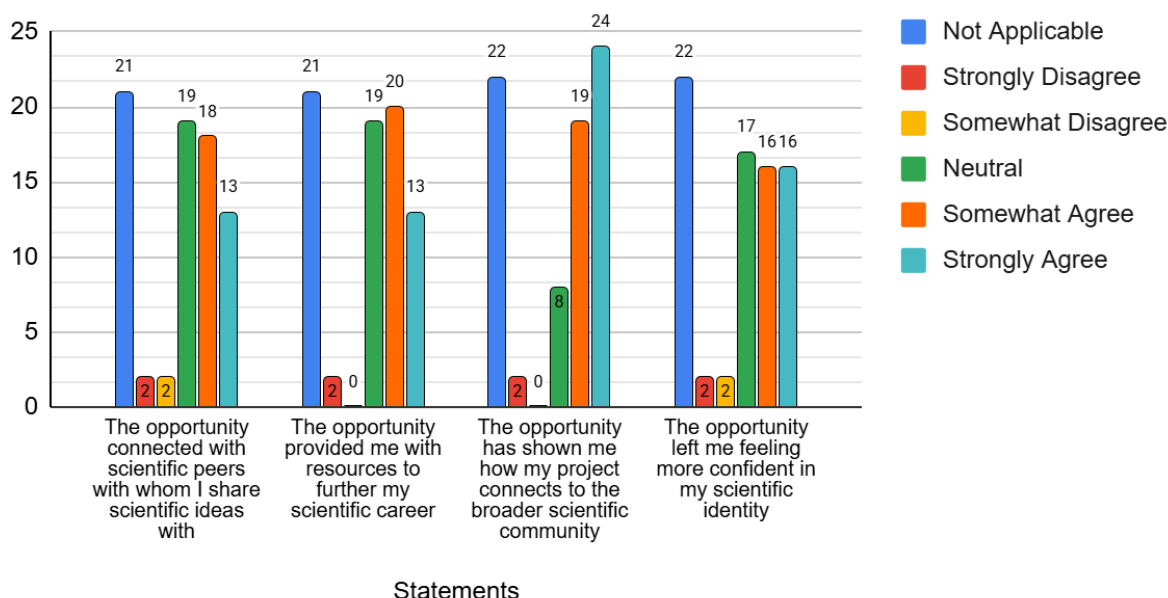


Figure 2.16: Student Responses to Survey Question 44 (If you had at least one of these opportunities (i.e. see Survey Question 41), rate your level of agreement with the following statements.)

Reliability Coefficients Example

Reliability for BURET-TAMUS or the consistency of the measured results of the instrument, can be assessed through various methods. Here, we provide an overview of 2 forms of reliability evidence for our instrument.

The first form of reliability evidence of our instrument is known as the separation reliability. As an example Upon calibration of both sets of teaching and mentoring data in BASS, separation reliability coefficients (EAP and WLE) were determined. These coefficients indicate the extent through which the instrument items are able to differentiate respondents at different waypoint levels by analyzing the proportion of variance in item responses. They also account for the proportion of the variance that is explained by the model in relation to the total variance (Wilson, 2023).

For the items related to exposure towards teaching practice, the EAP and WLE were found to be 0.898 and 0.811 respectively. The covariance was determined to be 2.305. In the mentoring set of items, the EAP and WLE were found to be 0.921 and 0.858 respectively, with a covariance of 5.551. There is room for improvement in these reliability coefficients, but we can declare that there is some consistency in differentiating respondents.

Instrument Validity

Validity for BURET-TAMUS can be assessed by gathering evidence in numerous forms. In this section, we detail 3 pieces of evidence in this section: Content Validity, Response Processes, and Internal Structures,

Content Validity is evidence that the content of the instrument has a substantive connection to the construct that is being measured. Here, we have demonstrated this connection through the outlining of the 4 building blocks of measurement (Wilson, 2023): The Construct Map, The Item Design, The Outcome Space, and the Wright Map which will be featured later in this section. Additionally, we have provided an overview of the literature in the *Introduction* to inform the background research context of our two constructs. These building blocks were reviewed by Dr. Mark Wilson and Department of Education graduate students at the University of California, Berkeley throughout the development of this instrument.

Response processes are validity evidence from analysis of individual responses. Some instruments may decide to perform this analysis through the instrument itself. However, due to the length of the instrument that was used in this pilot study, we decided to move forward with this analysis on a separate semi-structured interview protocol. Respondents on the consent form were asked if they wished to be contacted to participate in exit interviews after completion of the survey. The questions on the semi-structured interview protocol ask for further detail about aspects of teaching and mentoring featured in the survey and for further detail on the contexts of their URE. The interview protocol was designed to take about 30-45 minutes and students were given a \$25 Amazon Gift Card as compensation to participate in the exit interviews. The interview protocol is provided in the Appendices.

The timing of data collection and student availability during the month of December made it so 9 exit interviews were done with survey respondents. Interview data was cleaned and de-identified and later coded with a coding scheme containing 25 codes. We do not claim that students interviewed were representative of the entire data sample. All students that were interviewed had participated in UREs within the prior year.

From the analysis of the survey exit interview transcripts, we noted that students shared a common sentiment that their expectations of research were challenged once they began to participate in it.

I think this is something that is so, like, our expectations in our project is more like- we always seem to have like these lofty goals and like, "Okay, by the end of the semester, this is kind of where we want to be or by the end of the summer, this is where we want to be. By the end of this calendar year, this is where we want to be." We didn't really have, like, weekly deadlines or expectations. Just like every time we meet, you know, we get new tasks and we kind of go and work on them, explore them, and then come back. And then we do end up pushing back the deadlines as, you know, things go awry as research happens.

In the beginning, I was really hoping that research would give me a lot more intellectual freedom and independence to do what I want. My first research experience wasn't really that. It was more of, like, maintenance and more of, like, very basic tasks, repetitive tasks that you would do every single week for weeks on end. So it was a very slow process. I was told to do tasks rather than getting to choose the tasks that I wanted to do. It was different from my expectations. But I think as I matured in my research knowledge and in my skill set, I got more independence with the projects that I was working on. I think it has evolved a little bit more to be something where I like- I'm still, you know, doing menial tasks that you and I would rather not do. But I know exactly what I'm doing. I'm deciding that I want to do this so I can get this result. So I think as you get independence and you grow as a researcher, you kind of get more of that.

Yeah, I started doing research really wanting to lead a project. Have a project that's mine and, you know, get a publication and get multiple publications in undergrad to be a great researcher. That did not end up happening just because of the way that research works. And I think I went in with a lot of expectations of things working well and everything, but things ended up not working well, but that's still fine. And I've now learned to kind of actually enjoy the process rather than trying to go for an end result.

After my first experience, I expected my mentor to on day one at least, like, show me around the lab. Like, this is where we keep reagents, this is where we do our gels, or just walking me around. I don't know if this is a hope or an expectation, but for her to be like, attentive to me in certain ways, where it's like, if I am, you know, going to a new protocol, and I don't fully understand it, that I could go to her and ask her as a mentor. Otherwise, you know, show me around the project, what are we doing, what's going on? Maybe give me a couple of papers to read or something. If I asked for that, at least, that's really an expectation or something I like to do. That's most of it. That's most of what I expect when joining a lab.

Students also had some expectations for the role of their research mentors which would go on to shape several of their research experiences.

I guess, ah, my expectation for the role of my mentor is someone that would provide support for me in the lab setting. That is like when I come into the lab, I largely do my own thing at some point in time. After I get obviously onboarded and get familiar with the protocols that my mentor would help me so essentially, starting off day one, it would be mentor, my mentor would help me become accustomed to the protocols of the lab and then slowly become more independent over time where I was pretty much just like working side by side with them either on like a similar project, or like a sub part of the project. So I guess, starting off with a bit more of an instructional approach, and then slowly even more hands off over time.

Well, I definitely think the mentor, whoever it is, if it's, you know, a graduate student mentoring an undergrad or a postdoc, or whoever it is, I think they should be able to put themselves in the shoes of the undergrad, understand the experience level of the undergrad. You know, for me, that first lab, it was literally my first research experience, I didn't have any research experience in high school or, or anything like that. So it's basically to come in with no experience, it's kind of a big jump, to just start doing projects right away. So I think understanding the experience level of the mentee is very important. Um, being able to show them how the protocol is done, rather than just giving them like a piece of paper saying, here's the protocol, follow it, I don't think that's very useful, I think actually, showing them how the protocol is done, taking them step by step, kind of like how my new lab is doing it, where I'm kind of shadowing, I think that's very useful. Giving the mentee a way to reach out if ever there needs to be some troubleshooting or if they have any questions.

In addition, students often viewed mentoring as a one-sided transactional relationship between mentee and mentor which clashes slightly with our definition that was provided back in the beginning of this paper. If the majority of the sample held similar views of mentoring as did these students that were interviewed, it may have affected their responses towards some mentoring questions such as **Q14 (Please describe what actions your research mentor took to guide/support you at the beginning of the research project)** and **Q16 (Please describe how your research mentor provided you feedback on your research work).**

I think effective mentoring would be someone who would be a mix of the two summer experiences that I've had where the mentor should have availability such as time to first guide whoever their mentee is and then maybe have a project either they're working on that they can bring into with the mentee. Or some way or some plan for what the mentee should be doing.

I think in an ideal situation, the level of support you get would decrease or change where a grad student helps you like, become more independent, but at some point, they're only here to help you run your reactions, but at the end of the day, it's like, you're the one driving the project, or your subproject. But in the group that I am in, the grad students like to drive a lot more things. So I guess it should have changed, and it's not, which is why I'm leaving the lab.

I think that really just depends on the mentor-mentee relationship and what the mentor wants to get out of the mentee. And what the mentee wants to get out of that mentor. So I think effective is very subjective in terms of what each person wants out of the relationship. I will contend that if you were to establish a metric for effectiveness, it would potentially include something along the lines of, obviously, mentoring inside the lab. So initially beginning with something along the lines of maybe a bit more of a guided approach to learning. Depending on where your mentee is starting off, they have more experience, but like reading literature, and doing a literature review, less hand holding there. So more hand holding where the mentee requires hand holding and less hand holding where they're more experienced, and then slowly decreasing the amount of hand holding over time, helping the mentee get more independent.

When it comes to what would be considered effective teaching students responded with the following:

Yeah, I think effective teaching is definitely threading this fine balance of like criticism and, like, constructive feedback. So I think I really appreciate what my mentor currently does, where, you know, accepting failures and kind of, like, pushing more towards, "Okay, what can we do? What is the next step that we can do?" So I think, like, teaching as for undergraduate research should definitely highlight that, you know, research doesn't always go according to plan, and failures are pretty common and kind of highlight that. The main thing is learning from it because any results are good results, bad results are also good results that you can learn from and propelling towards what's the next thing that you try?

I think having the ability to, you know, talk to the mentee in a respectful way. Explain where they went wrong without, you know, chastising them or whatever. So that the mentee realizes their mistakes and is willing to learn and not be afraid to make more in the future. I mean, that's what learning really is, is learning from the mistakes. And so to do that, mentee has to feel like they can make mistakes, of course, not on purpose, but you know, just following the protocol, if something goes wrong, they should feel free to be able to talk to the mentor and ask for help and not be in fear of being punished basically.

Other interesting tidbits from the survey exit interviews are as follows:

As far as the project goes, however, because I didn't have a direct mentor or a project, then it was kind of very much like, um, on my own to really push and make that initiative to make that happen because I also had a presentation at the end of the thing. I was like, even though they knew that I needed to do that, it wasn't necessarily, I guess, their problem kind of deal. If that makes sense, it wasn't necessarily their duty to ensure that I do that. That was a thing initially in the beginning, for the first month or so where I was like, she's like, "Oh, well, I'm busy, but maybe you can ask someone else" and I'm like, "Okay, well, I asked that person." They're like, "Oh, I'm busy, ask someone else." I was running around. There was a communication barrier in that sense where I was trying to communicate my need for something, and that wasn't really reciprocated.

Um, I knew some things like NMR and, I guess, how to run a reaction, but there was a lot of new things that I had to learn, using different instruments and just the general project. There's a lot of different changing parts and moving parts. So yeah, he did teach me a lot. I think a lot of it was just like sitting down and me asking a lot of questions. Yeah, I think the biggest thing with research is just being open to learning and asking your mentor questions. And the biggest thing for a mentor is being willing to listen and patience. Um, yeah, I think another thing that helped me was, I knew that my grad student trusted me with what I was doing in lab. So I could- if I didn't know something, I would tell him and then he would watch over me while I do it once, so I feel comfortable with it, and then I can do it alone later. But yeah, I think, trust and also showing somebody hands on how to do it first before they do it is really useful.

So in the beginning, I was really just trying to find any and all type of research that I could get access to. So it was a lot of, like, sending emails and trying to see who would take me. And as a freshman, that was really hard and people wouldn't really take me. So I started off just like, there was a club that offered undergraduate research, so I went there just to, like, you know, do some type of research. And then I got research through, like, my professor that I was in. After asking him and talking with him for a semester, he let me, like, join his lab over the summer. Um, but I think I was really trying to figure out what is the niche of research that I like. I didn't start off as both bioengineering and EECs, but I slowly fell in love with that intersection, which is the research that I do right now, which is what I really like. I was kind of jumping around and exploring different types of research before I came to the niche that I'm now really passionate about.

Yeah, I think, um, I think the current project that I'm in because it's a separate subgroup within the overall lab. So we're not super involved in what the rest of the lab does. We're a focus group for this specific project because we're trying to- we're trying to really get this project moving in the next year to try to get publication and everything. So it's a very focused small, focused group. So I think that's one of the drawbacks of the current lab situation that I'm in is that we don't have as much access to the overall lab. My previous lab was like the organic chemistry lab. I was like, part of the lab. And so, you know, we'd have our lab meetings every week with all the different postdocs presenting their work and kind of and I'd be there in person, too, because it was a wet lab. So I feel like there I was like, more part of the lab culture. Whereas right now because we're like a smaller focus group, I'm not really as much involved within the whole lab culture, especially because most of the work that we're doing is online and we touch base through Zoom..

I guess, it might have been just a little bit more independence. When I was working in the lab, I had a very good understanding of what the project was about. But I guess the way that my mentor kind of approached the research project was very much like we're doing this today, we're doing this today. And so there wasn't, I didn't really have a good grasp of the larger picture of what our plan was going to be for the project. Like I knew what the project was about, I understood conceptually what we were trying to do. But I didn't understand at least specifically what we were going to do on a day to day basis to achieve that. So I guess in that regard, maybe it was earlier on, I was kind of dependent on my mentor for my day to day basis to then come in and say we're doing this today.

I think research is a valuable thing in terms of finding something that you're interested in first. And then pursuing that research and something that's very, very different from academia. So it's very, very different than being instructed on like, "Hey, here's a concept. Here's our work in theory. And then here's how you write an answer on it and take an exam." It is very investigative, you're kind of approaching yourself, you're either making a problem, I like investigating a problem, either one that you've like, found out of yourself, generate yourself, or have come up with like a pie telling you what the problem is. And you're trying to find a way to solve it yourself. So it involves a lot more critical thinking, then, I guess, sitting in a lecture, or solving some problems, that's underwriting questions on the exam, which obviously requires critical thinking and a bit of creativity. But research definitely, I think, does that to a much larger degree.

His method for teaching me protocols and stuff was to have me watch once. And then the next time I had me do it while he was and then the third time do it independently. We like working right next to each other. So I could always ask questions. And he was always really good. Like, when I first joined, I was given a project to work on. So I was always given a level, I wasn't just an assistant, I was given a level of research independence that was really valuable to me. And even when talking about his projects, or getting helpful mine, he was always making sure I was thinking about the larger context of the project and like experimental design. So when I first started out there were methods of teaching, and then papers and talking about those and slowly became kind of like supporting me as I independently lead the project.

Additionally, I would say, I mean, I'm very comfortable asking questions, but he'll always stop in case I'm curious. With anything, he'll tend to, like, explain, like, the overarching goal of the product of like, whatever I'm trying to learn or like the reasoning for that. And then he'll get into the nitty gritty of what each step does, or like, why certain details are important. And will also kind of challenge me to like, sometimes he will leave things purposefully. They like that, and like asking me what I think. So it's not just explaining, but there's also kind of like a dialogue, or he's pushing me to think about it. And guess, and sometimes I'm wrong. Often, I'm wrong, but at least it helps me think more critically about whatever he's teaching me.

Future iterations of this instrument will take into account the insight gained from these student responses when designing teaching and mentoring items for measurements. The last point of interest that was gained from these interviews was that students provided positive feedback on the survey format and items and had little to no suggestions for changes that should be made.

Some demographic items also asked respondents for more information on their research experiences and for feedback on the instrument itself. These items were free-response and voluntary. An overview of responses to these items indicate that many students received the survey positively, as they felt that they were able to express their research experiences through the teaching and mentoring items. There were a few students who felt that they had difficulties with responding to the items that did not properly match their experiences or did not give them the option to select a more “negative” option. These comments were not unexpected and in the future, we may be able to expand the item design to accommodate more respondents.

Internal Structure is evidence of a connection between the measured constructs and the empirical results. This can be established through the Wright Maps. The Wright Maps are useful visualizations of the distribution of item responses and how they map onto certain thresholds based upon the statistical models that were described in *Methods*. Alongside other parameters that have been discussed previously in this report, Wright Maps can also provide insight into potential item misfits and patterns that may exist within student experiences with teaching and mentoring that they had in UREs. The Wright Maps by Waypoint level for the Teaching and Mentoring Practices are given in Figure 2.17 and 2.18, respectively. The research team has also added some marks onto these figures. The gray lines that run across the Wright Map are meant to illustrate the “banding.” Banding separates the item responses into distinct waypoint levels with logit units where the boundaries are set by the black lines. Banding allows us to note overlaps and outliers in items and responses.

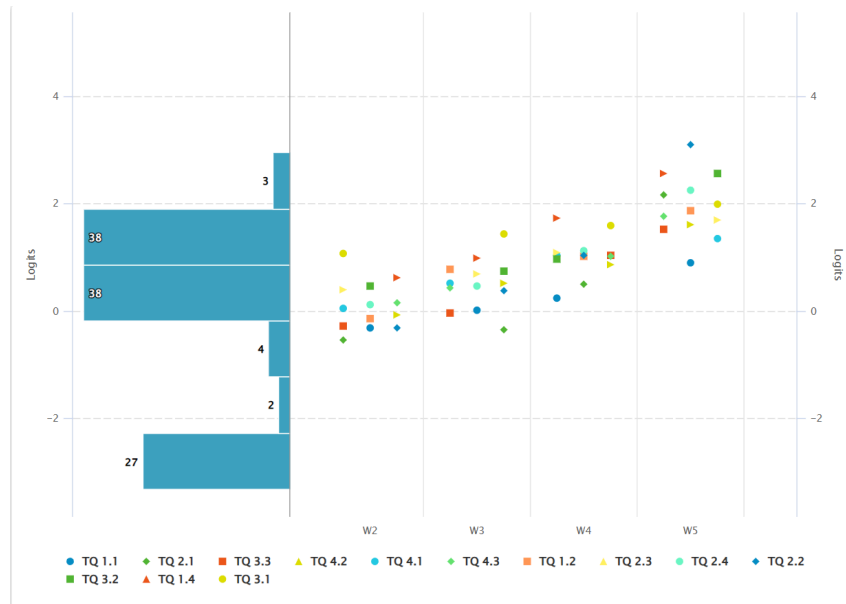


Figure 2.17. Wright Map by Waypoint Level for Teaching Practices

From the Teaching Wright Maps, there are a few observations that we can make. We included teaching practices that were not featured in BURET-TAMUS to check on how they would perform under this calibration and against the teaching practices that actually were in BURET-TAMUS out of curiosity on the subject. On the Wright Map, the items corresponding to BURET-TAMUS are TQ 1.1 (Q9. Please describe what actions your research mentor took to teach you scientific knowledge (e.g. facts, theories, principles) for your research project.), TQ 2.1 (Q10. Please describe what actions your research mentor took to teach protocols and techniques for your research project.), and TQ 2.2 (Q11. Please describe what actions your research mentor took to teach you data analysis for your research project.). The majority of respondents for these questions were within roughly 0 to 2 logits. This indicates that they tended to score higher on the construct map for these items (meaning that they reported that they were more active learners and their mentors provided them with more agency) which somewhat aligns with what we observed looking at the individual item responses and the exit interviews. When looking at the banding for this Wright Map, we see that trying to separate the data into distinct waypoint levels leads to a lot of overlap between them. In particular, for TQ1.1 (Q9), TQ2.1 (Q10), TQ2.2 (Q11), the responses were similar at the lower waypoints, but deviated a bit more at higher waypoints. For example, Q11 saw distinction between responses at higher waypoints which means that students experienced higher integration of teaching practices for data analysis than for something like being taught STEM content knowledge. It may also imply that the item responses are not meaningfully distinct enough across the different waypoints for respondents in this calibration.

It is plausible that the variety that is seen in UREs make it unlikely that there would be heavy distinction in the teaching of general research aspects or it could be plausible that research mentors did not exhibit a variety of teaching practices throughout the student's experience. However, the efforts made to create distinct waypoints to

account for this variance might need additional review or development. Certain items also experienced less banding than others which could mean that item design for some teaching and mentoring items should be revisited in the future and expanded upon.

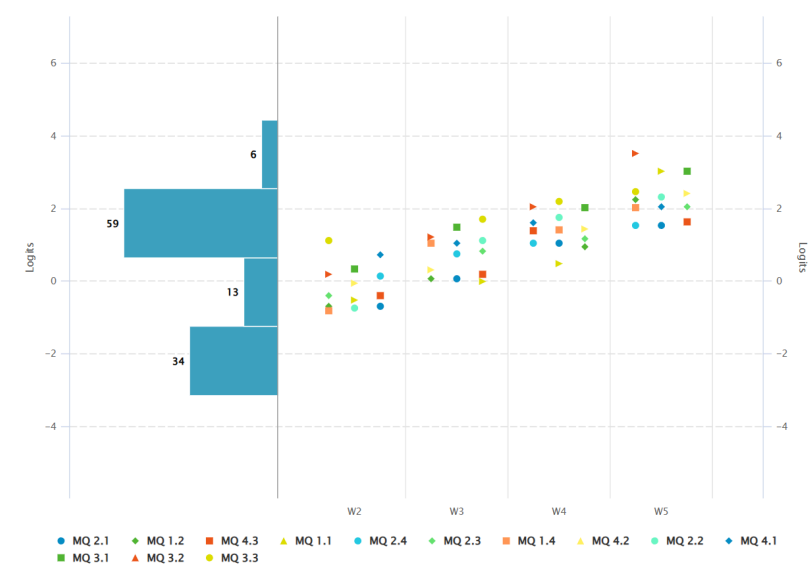


Figure 2.18. Wright Map by Waypoint Level of Mentoring Practices

From the Mentoring Wright Maps, there are a few observations that we can make. We included mentoring practices that were not featured in BURET-TAMUS to check on how they would perform under this calibration and against the mentoring practices that actually were in BURET-TAMUS out of curiosity on the subject. On the Wright Map, the items corresponding to BURET-TAMUS are MQ1.1 (Q14. Please describe what actions your research mentor took to guide/support you at the beginning of the research project.), MQ1.2 (Q15. Please describe what actions your research mentor took to set expectations for the research project.), MQ2.1 (Q16. Please describe how your research mentor provided you feedback on your research work.), MQ4.1 (Q13. Please describe what actions your research mentor took to help you to communicate (poster presentations, oral presentations, lab reports, research group meetings, etc.) your research findings?), and MQ4.2 (Q17. How did your research mentor foster your independence during the research project, if at all?). The majority of respondents in Figure 21 are within 0 to 2 logits. This indicates that they tended to score higher on the construct map for these items (meaning that they reported that they were more actively engaged, felt well-supported in the URE, and that their mentors provided them with more agency) which somewhat aligns with what we observed looking at the individual item responses and the exit interviews. Compared to the teaching items, the mentoring items saw less overlap between waypoints, meaning that the students were able to fit their experiences onto our construct map in a more distinguishable way. Notably, these results indicated that students reported a high level of mentoring support towards the beginning and end of the URE which corresponds to MQ1.1 (Q14) and MQ 4.1 (Q13) since these two mentoring questions had more students distributed across the higher waypoint levels than the others. It's possible that this corresponds with what

students reported in other components in the survey and in their exit interviews, where at the beginning of a URE, they received a lot of support from their mentor to get started on a project and at the end of a URE, students received support putting together materials for scientific communication which is commonly expected in many UREs. Students also reported feeling like they were becoming more independent researchers throughout the URE based on MQ4.2 (Q17) scores being located more towards the higher end waypoints on the mentoring construct map.

Statistical Analysis - Exploratory Factor Analysis

Exploratory Factor Analysis (EFA) is a statistical technique that can be used to identify the number of hidden factors (or latent variables) that are not explicitly being measured by the instrument, but are influencing the data that is measured to a certain extent. EFA was done with the BURET-TAMUS data to see if we could obtain some useful information on which items might share some trends or connections that were less obvious under other approaches. As with our other statistical tests, EFA was done through a built-in package within RStudio.

In RStudio, one must input the number of assumed hidden factors into the model before the computation. We experimented with different numbers of hidden factors in RStudio (such as five hidden factors), but in the end we settled with three factors as it provided the most reasonable output that we could use. If we assume three factors, then we can obtain other useful parameters from EFA such as the “Uniqueness Parameter” which is defined as the variance in an item that is not shared with the other items and “Factor Loadings” which is defined as the amount of variance in an item that can be attributed to the hidden factors. In the two tables, below we share the unique parameter (Table 2.1) and factor loadings (Table 2.2) respectively for a set of items that were inputted into RStudio to perform EFA. We selected these items as they were representative of each of the factors we measured in BURET-TAMUS and their item design was compatible with EFA.

Table 2.1: Unique Parameters for Representative Items Selected for EFA

Q4	Q5	Q7	Q21	Q22	Q25	Q26	Q29	Q34	Q35	Q36	Q40
0.600	0.887	0.815	0.692	0.827	0.713	0.941	0.651	0.758	0.005	0.666	0.772

Table 2.2: Factor Loadings for Representative Items Selected for EFA

	Q4	Q5	Q7	Q21	Q22	Q25	Q26	Q29	Q34	Q35	Q36	Q40
Fact1	-0.16	0.12	-0.34	0.11	0	0.24	0	-0.17	0	0.98	0.42	0
Fact2	0.40	-0.17	0.26	-0.54	0.39	-0.28	-0.22	0.56	0	0.18	0	0
Fact3	0.46	0.26	0	0	-0.15	0.39	0	0	0.48	0	0.38	0.47

This data indicates that the student responses for these BURET-TAMUS items are being moderately influenced by at least three hidden factors. The factor loadings, in particular, show that the items might be more correlated with some of these hidden factors than they are with some of the actual measured factors that comprised BURET-TAMUS. We can also see this influence in the Chi-Square Statistic that was obtained from EFA. A large value of Chi-Square with a low amount of degrees of freedom such as what we obtained (45.26 on 33 degrees of freedom) is evidence of this influence on our data from these hidden factors. The P-value for EFA was determined to be 0.0758.

MIRT Takeaways

The following is an overview and discussion of the results we obtained from our MIRT analysis in RStudio. The RStudio MIRT model defaults to 5 factors and is utilizing the 'BL' method of estimation. First, we show the factor correlations (Table 2.3) as generated by the MIRT model. Factor correlations describe the relationship between the hidden factors to each other. The factor correlations suggest that the hidden factors are not influencing each other very much which supports the idea that they are instead having more influence on the measured item responses in BURET-TAMUS.

Table 2.3: Factor Correlations from MIRT

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
Factor 1	1.000	-0.210	0.387	-0.430	-0.258
Factor 2	-0.210	1.000	0.343	-0.129	0.254
Factor 3	0.387	0.343	1.000	-0.504	-0.332
Factor 4	-0.430	-0.129	-0.504	1.000	0.188
Factor 5	-0.258	0.254	-0.332	0.188	1.000

The MIRT model also generated factor loadings and rotated factor loadings. The rotated factor loadings are presented in Table 2.4 below for a set of representative items of each construct in BURET-TAMUS. Rotated factor loadings are a transformation of factor loadings. This transformation is done to change the factor loadings into results that can be interpretable to correlations between hidden factors and the item responses. The "h2" value in this table is the squared factor loadings which assesses how much variance in each item's response data is coming from the latent factors. A higher value indicates a positive relationship between that item and the hidden factors.

Table 2.4: Rotated Factor Loadings from MIRT

	Q4	Q5	Q7	Q21	Q22	Q25	Q26	Q29	Q34	Q35	Q36	Q40
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Fact 1	-0.087	0.018	0.040	0.36	-0.0018	0.49	1.029	-0.61	-0.053	-0.064	0.025	-0.31
Fact 2	0.96	0.63	-0.0044	-0.070	0.11	0.35	-0.020	0.27	0.26	-0.031	0.44	0.075
Fact 3	-0.13	0.43	-0.054	0.19	0.12	0.40	-0.087	-0.15	0.16	1.026	0.23	-0.58
Fact 4	0.069	-0.20	0.025	-0.63	0.99	-0.11	0.073	0.31	-0.84	0.064	-0.17	0.28
Fact 5	0.061	-0.16	0.97	-0.090	0.190	-0.30	0.068	0.15	0.29	-0.056	0.35	-0.017
h2	0.94	0.98	0.98	0.98	0.98	0.99	0.93	0.99	0.99	0.97	0.53	0.86

To summarize the takeaways from this table, the squared factor loadings reveal that most of the representative items chosen to be featured in the MIRT model had a positive relationship with hidden factors. This is yet another piece of evidence that demonstrates that the factors we measured for in BURET-TAMUS may be more correlated with hidden factors that we did not measure than with each other. In the next table (Table 2.5), we share the sum of squared factor loadings which is another transformation of the factor loadings to assess how much of the amount of variance from the total item responses are from each of the hidden factors in the model. A value close to or greater than 1 indicates a large contribution of variance from the hidden factors which is indeed the case in our modeled data.

Table 2.5: Sum of Squared Factor Loadings from MIRT

Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
1.897	1.78	1.916	2.366	1.354

Item Correlations

Table 2.6: Item Correlations for Representative Items from Factors in BURET-TAMUS

	Q4	Q5	Q7	Q21	Q22	Q25	Q26	Q29	Q34	Q35	Q36	Q40
Q4	1	0.15	0.14	-0.26	0.096	0.016	-0.057	0.19	0.15	-0.089	0.082	0.19
Q5	0.15	1	-0.15	0.289	-0.01	0.17	0.14	-0.11	0.16	0.087	0.077	0.057
Q7	0.13	-0.15	1	-0.14	0.23	-0.2	0.11	0.21	0.14	-0.29	-0.016	-0.13
Q21	-0.26	0.29	-0.14	1	-0.18	0.21	0.045	-0.29	0.14	0.014	0.11	0.042
Q22	0.096	-0.019	0.23	-0.18	1	-0.11	0.092	0.24	-0.25	0.11	-0.15	-0.026
Q25	0.016	0.17	-0.22	0.21	-0.12	1	0.021	-0.21	0.13	0.18	0.24	0.36
Q26	-0.056	0.14	0.11	0.044	0.092	0.022	1	-0.3	-0.025	-0.12	0.13	0.057
Q29	0.19	-0.11	0.21	-0.29	0.234	-0.21	-0.3	1	0.017	-0.066	-0.23	-0.071

Q34	0.15	0.16	0.14	0.14	-0.25	0.13	-0.025	0.012	1	-0.055	0.27	0.23
Q35	-0.09	0.088	-0.29	0.014	0.11	0.18	-0.12	-0.066	-0.055	1	0.39	-0.014
Q36	0.082	0.077	-0.016	0.112	-0.15	0.24	0.13	-0.23	0.27	0.39	1	0.11
Q40	0.19	0.058	-0.13	0.043	-0.027	0.37	0.057	-0.071	0.23	-0.014	0.11	1

The final component of our MIRT analysis was checking the item correlations directly to see if any of the constructs show strong relationships with each other. This would serve as direct evidence for whether or not the factors in BURET-TAMUS were manifesting in each other's student item responses. We obtained the Item Correlations in Table 2.6 from the *correlation matrix* package with the same representative items as in the previous statistical technique. The output reveals the model items and to an extent their corresponding constructs have essentially no statistical correlation with one another.

Therefore, we were able to descriptively learn a great deal about the student experience with many different factors that could be present in a URE with BURET-TAMUS, but we were unable to confirm that these factors are statistically correlated or working in tandem to support student's development. However, we collected pieces of evidence on the presence of hidden factors so it is plausible that perhaps we may have observed a correlation between research factors had we opted to test and measure different ones in BURE- TAMUS. Still, evaluating the constructs individually provided some interesting insights into the student point of view in UREs and the some of the individual constructs performed well statistically (decent fitting parameters or statistical coefficients), performed well in terms of reliability, and performed well in terms of being able to cleanly map the construct, items, and item responses to each other via the Wright Maps obtained from the BASS calibration.

Recommendations

The research team gained valuable experience in the process of instrument development and measurement. Prior to the writing of this report, the research team has already begun to share and discuss modifications and optimizations that can be made for this instrument in future measurements. In the future, the research team aims to continue to expand the capabilities of the instrument.

From our results, we observed that improvements can be made to the waypoints of the construct maps to help better distinguish them from one another. In addition, we may consider adding additional waypoints to include more "negative" experiences that respondents can map onto. Another idea that has been shared is to create a "branch point" in the instrument so that respondents who do not have research experience can answer a select set of questions where they can share why they have not participated in research experiences or what their ideal research experience would look like. An idea such as this may require the creation of a third construct map which could further complicate data analysis though. Due to the presence of hidden factors in our data set, a researcher looking to perform a similar study may consider trying out different

constructs than the ones we used or even expanding the survey with additional items or item types.

Another improvement can be made in the item design and outcome space. We observed during the calibration phase of this analysis that respondents had difficulties with a few items relating to teaching and mentoring. A more streamlined bundle of items could help improve the mapping that we receive from their item responses. In general, the survey instrument proved to take slightly longer to complete than we had anticipated. Therefore, the removal or combination of certain items could be on the table for the future. New item types are also planned to be used in future measurements as the research team believes that it may prevent respondents from reading as much text and thus, becoming fatigued with the survey.

An idea for instrument optimizations comes in the form of control variables. Due to the nature of the sample and the circumstances regarding data collection, we allowed any student to participate in the study despite knowing that some students would not map cleanly onto some of the measured constructs. It is admittedly difficult to control for external variables or hidden factors due to how different a URE can be from one student to another. Any future measurements must take into account the effects of such differences in participants on the instrument design, calibration and analysis.

Conclusions

We developed a survey (BURET-TAMUS) to learn more about the student experience of participating in UREs across many different factors and through the impact of what teaching and mentoring practices the students were exposed to. In addition, we were interested in seeing if the factors were influencing and/or aiding each other in shaping the student experience in UREs. From our survey measurement results, we found that the amount of agency and support that students receive from teaching and mentoring in UREs respectively is incredibly varied. Analyzing responses across all of the items highlighted critical aspects of the student experience in UREs that are underappreciated or not well-considered.

Analysis of qualitative survey data and survey exit interviews provided additional insights into how students are experiencing several different factors of research experiences in their UREs along with specific examples of impactful teaching and mentoring practices that they attributed to their academic and professional development. Calibrating and fitting the individual constructs through a modified Rasch Model, we see satisfactory reliability coefficients, item parameters, and Wright Maps which indicates that the Construct Maps and items are performing well with responses mapping on to each other accurately. This helps determine where students would be located on each of the Construct Maps and thus, we can make assertions about their URE experiences.

Statistical Analysis with Exploratory Factor Analysis (EFA) and Multidimensional Item Response Theory (MIRT) indicates that the research factors that we attempted to measure with our survey don't really influence each other which could indicate either that we did not test a suitable combination of research factors or that the lack of clear correlations between factors is indicative of the slightly disjointed and less structured UREs that students experienced. Another scenario is also plausible. We did collect a lot

of evidence towards the presence of hidden factors, which are factors that are not explicitly measured in the instrument, but are influencing the data anyway. At this moment in time, we can only hypothesize the cause for the lack of correlation of BURET-TAMUS factors.

On implications for how to approach undergraduate teaching and mentoring in UREs, our survey supports the idea that an integrated network of mentoring and teaching practices is required for students to get the most value out of their research experiences based on the factors that exist both in and out of the research lab and were reported in the student survey responses. For example, students described teaching practices related to “reaching the student where they are at and going at their pace” to be the most effective for them. Students also described mentoring practices related to “communication, independence, and setting realistic goals” to be helpful for them in terms of getting them to be comfortable with learning how to navigate their lab environments and academic culture. In the future, we plan to refine and expand on the constructs, items, and samples of students that we measure with BURET-TAMUS.

Chapter 2 Contributions

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Chapter 3: BURET Bring Out the Best in your Undergraduate Workshop Series: Evaluating Changes in Teaching and Mentoring Practices between Graduate Student Mentors and Undergraduate Mentees in a Research Experience after Training Workshops and Coaching Sessions (Project 3)

Introduction

The previous two chapters of this dissertation highlighted the impacts of undergraduate teaching and mentoring in UREs through K-12 STEM teachers and through direct surveying of students across many different research factors. However, in the BURET project, we also place special significance on the research mentors who are responsible for teaching and working with the undergraduate students who participate in UREs. We focus on these research mentors because they commonly engage with the undergraduate student the most out of all members of the research team, but also because they too are capable of benefiting from being a research mentor (Dolan & Johnson, 2009). This chapter describes how we conducted a research study from an initiative to train graduate students and post-doctoral scholars at our institutions on teaching and mentorship of undergraduate students, and, in the remainder of this section, we rationalize our interest in studying this specific population for the research study.

Graduate students and post-doctoral scholars are primarily responsible for most undergraduate teaching and mentoring that occurs in research (Cotè, 2024). Approximately, 94% of doctoral students will engage with teaching and mentoring of undergraduate students over the course of their programs (National Academies of Sciences, Engineering, and Medicine, 2018; Thiry & Laursen, 2011). However, most graduate student mentors receive little training to support an undergraduate student in research. They may struggle to effectively distinguish between teaching and mentoring because their main responsibility is conducting research and they may not proactively integrate various teaching and mentoring practices based on the student and project needs (Amundsen & McAlpine, 2009; Ruben, 2020; Titus & Ballou, 2013).

The extent of the benefits (Aikens et al., 2016; Goodwin et al., 2023; Hund et al., 2018; Linn et al., 2015; National Academies of Sciences, Engineering, & Medicine, 2019; Taraban & Logue, 2012; Rodenbusch et al., 2016; Watts & Rodriguez, 2023) that undergraduate students gain from participating in UREs corresponds to the effectiveness of the teaching and mentoring they received from their mentors (Ann Mabrouk & Gapud Remijan, 2023; Estrada, Hernandez, & Schultz, 2018; Hernandez et al., 2018; Morales, Grineski, & Collins, 2024). Therefore, it is important to adequately prepare graduate students and post-doctoral scholars on effective undergraduate teaching and mentoring practices so that undergraduate students can maximize the benefits they experience from URE participation. As part of the BURET project, we addressed the lack of preparation that graduate students and post-doctoral scholars at our institution have for undergraduate teaching and mentoring in research by inviting them to a workshop series led and organized each summer by the BURET research team. This is known as the BURET Bring out the Best in Your Undergraduate Researcher (BURET-BOBYUR) Workshop Series. The BURET-BOBYUR Workshop series has been operating for several years at our institution at the time of writing. In this work, we sought to reinforce and investigate teaching and mentoring through the development of researcher-led “coaching sessions” with mentors who participated in the BURET-BOBYUR Workshop Series. In the *Background* and *Theoretical and Other Frameworks* sections of this chapter, we provide further rationale and describe our interest in putting together the workshop and coaching sessions in the way that we did based on an overview of the literature.

Background

Awareness and Implementation of Practices Facilitate Effective Teaching and Mentorship of Students in UREs

As mentioned in the previous chapters of this work, research in the BURET project considers teaching practices and mentoring practices to be distinct from each other, but often occur in tandem (Cotè, 2024). As an example, in a research context, a graduate student mentor could attempt to teach their undergraduate mentee a new skill while also mentoring them by normalizing failure or assessing knowledge to develop the mentee as a scientist. However, some research mentors who typically work with undergraduate students (including some research faculty) are not able to distinguish between different teaching and mentoring practices.

Research mentors who are able to distinguish between teaching and mentoring practices are better prepared to integrate these together when working with undergraduate students. Better integration of teaching and mentoring practices lead to more thorough and tailored development of undergraduates students into STEM researchers. In addition, being more aware of teaching and mentoring practices and their unique use cases can prepare mentors to support students from a more diverse range of backgrounds and identities. For instance, work by Atkins et al. (2020) and Robnett et al. (2018) indicate that mentoring practices used in tandem that promote student efficacy, resilience, and scientific identity are particularly beneficial to students who identify as Black, Indigenous, low-income, and/or first generation to college. Atkins et al., 2020 also report that female students and students that are of a racial-ethnic minority group benefit from having shared values with their research mentors.

Other research studies (Myers et al., 2018; Brookfield, 1995; Malachowski, 1996; Wallin & Adawi, 2018) have suggested that undergraduate students can experience increased benefits from participating in research if their research mentors have had space to reflect on their roles and the practices they can implement in the research lab. This sort of personal reflection in research mentors is sorely missing from the typical graduate experience in many higher education programs (Emery et al., 2019; Hall et al., 2018; Hayward, Laursen, & Thiry, 2017). For that reason, we have not only organized the BURET-BOBYUR Workshop Series, but have designed its curriculum to train research STEM mentors on proactively using teaching and mentoring practices and to provide them space to reflect on how they are implementing said practices with their undergraduate mentees. The curriculum itself incorporates many different theoretical frameworks which is further elaborated on in the *Theoretical and Other Frameworks* section of this chapter. With BURET-BOBYUR, we are hoping to address this first research question: *What aspects of the BURET-BOBYUR Workshop Series are being translated to actual undergraduate teaching and mentoring in UREs?*

The Use of Coaching and Other Interventions for the Training of Undergraduate Teaching and Mentoring in UREs

Although graduate students take the role of research mentors of undergraduate students during UREs due to their focus and proximity to the inner-workings of the

research lab, many of them receive little training or lack experience with teaching or mentorship (Amundsen & McAlpine, 2009; Ruben, 2020; Titus & Ballou, 2013). Proper training of graduate students to be research mentors themselves is unfortunately not emphasized or required in many UREs. There are some studies in the literature, however, that explore the impact of mentorship training on undergraduate student outcomes in UREs. In their 2007 study, Philion argued that frequent training of mentors where they can discuss challenges or ideas for their role as a mentor was found to be more effective at developing skills at mentoring than a single session in their student mentoring program. These student mentors also had the opportunity to interact with each other to share ideas or revise their mentoring approaches.

Fletcher and Mullen (2012) posit that programs, such as those that host or organize UREs, should have an understanding of what undergraduate students should take away from the experience and then train research mentors to ensure the desired outcomes of the program. The Annenberg Institute for School Reform at Brown University worked on a study (King et al., 2004) where they determined several areas where coaching of teaching practices can lead to professional development. Coaching, here, is a collaborative and reflective endeavor. It is recommended in King et al. (2004) to provide space to those being coached to apply what they learned from the coaching after careful reflection of past “teaching moments.”

At the University of Wisconsin-Madison, Pfund et al. (2006) held the *Wisconsin Mentoring Seminar*. This was a seminar focused on training research mentors to communicate effectively, having them be mindful of human diversity, discussing different mentoring approaches, and to incorporate “scientific teaching” to mentoring. The program consists of eight seminars taught by faculty and staff that applied a collaborative, iterative approach in its design with many writing assignments, discussions of time-management strategies, group exercises, and engagement with the literature. Pfund et al. surveyed over 80 research mentors in their study and controlled for research mentors who did or did not complete the *Wisconsin Mentoring Seminar* to compare the seminar’s effectiveness. Their results indicated that “trained” mentors were more likely to communicate expectations with their undergraduate mentees, had increased awareness of issues regarding diversity, and discussed mentoring with their peers compared to the control group. The trained mentors also communicated in their writing that they were more motivated to improve their assessment of student understanding and independence. Undergraduate students were also surveyed and they reported that the trained mentors were more interested and engaged in their development and independence than their prior mentors who had not taken the *Wisconsin Mentoring Seminar*.

Among these studies, certain elements of coaching and helping research mentors stood out. These include: regular coordination between the research mentor and the coach, collaborative and reflective sessions discussing mentoring practices, opportunities for the mentor to iterate on their mentoring approaches, and connecting mentoring goals with beneficial undergraduate student outcomes. We believed that synthesizing these elements together into a type of coaching intervention would be the ideal complement to the training and activities featured in the BURET-BOBYUR Workshop Series and would contribute more insight into a research topic that has little exploration in the literature. Thus, we designed and executed (See *Theoretical and*

Other Frameworks and Methods sections in this chapter) coaching sessions that would help certain workshop participants to improve their undergraduate teaching and mentoring and we aim to study their effectiveness in this study by answering the second research question of the study: *Can researcher-led coaching sessions with research mentors from BURET-BOBYUR enhance or complement their teaching and mentoring practices for supporting undergraduate students in UREs?*

Theoretical and Other Frameworks

Knowledge Integration (KI)

The primary theoretical framework that is utilized in this project is the Knowledge Integration (KI) framework (Linn & Eylon, 2011; Linn, 1995; Linn, 1991; Linn, 2000). KI can be used to design learning environments to teach students knowledge of scientific content and practices. The framework has four components that highlight activities by which students grow a coherent understanding of science when they combine their current knowledge set and ideas with new ones. In the case of UREs, undergraduate students learn important knowledge needed for their research projects by using their current knowledge to navigate getting started on a research project and then combine that with new ideas as they work through the project to gain mastery and independence (Linn & Eylon, 2011; White & Gunstone, 2014).

Undergraduate students are expected to exhibit knowledge integration during UREs and as such, we made it a priority in the BURET-BOBYUR Workshop Series to have participants understand this framework. Awareness of KI can also provide information to research mentors and what to teach their mentees to facilitate learning. KI is a key factor in “Progression of Learning” which maps out what novice researchers need to learn to move towards being an expert on a research project.

Tripartite Integration Model of Social Influence (TIMSI)

In the BURET-BOBYUR Workshop Series, the connections between how mentees learn, gain self-efficacy, and develop their scientific identities is explored through Kelman’s Theory of Social Influence (Kelman, 2006) which is also known as the Tripartite Integration Model of Social Influence (TIMSI). According to TIMSI, social influence of the scientific community is essential for understanding how aspiring scientists develop. There are three levels of social influence. The first is that undergraduate researchers accept the rules of the scientific community and try to establish self-efficacy. The second is that undergraduate researchers start to identify with the scientific community. The third is that undergraduate researchers eventually learn and adopt the values of the scientific community.

UREs directly immerse undergraduate researchers into the scientific community which lead to this social influence when individuals in the research laboratory comprise a community of practice that contributes to research learning (Lave & Wenger, 1991). As we progressed through the BURET-BOBYUR Workshop series, we supported the participants in enhancing undergraduate learning through integrating TIMSI in some of

the workshop content. In addition, we also assisted the participants to promote their community of practice.

Entering Mentoring

Entering Mentoring served as the inspiration for some of the BURET-BOBYUR workshop curriculum, the iterative approach to the workshop, and the general program of the series (Handelsman et al., 2005). Entering Mentoring is a seminar that takes a systemic approach to teach people how to be mentors. Similar to BURET-BOBYUR, the seminar engages mentors with frameworks, activities, and a forum to explore various teaching and mentoring practices. The seminar takes place over several sessions that involve topics such as learning to communicate, setting goals and expectations, evaluating mentoring progress, constructing a mentoring philosophy, and more. Participants who participated in the sessions had the opportunity to provide feedback and evaluation at the end which we also had in our own BURET-BOBYUR Workshop Series.

Indicators for Integration of Scientific Practices and Content

The Indicators for Integration of Scientific Practices and Content were developed by Helix et al. (2022) from insights gained from the literature to study how undergraduate students are integrating their understanding of foundational scientific practices. Helix et al. originally applied these Indicators towards evaluating student learning in UREs from poster presentation materials and from written student reflections about their research projects. The Indicators have been used over the years to develop instruments in other BURET projects. In BURET-BOBYUR, we have used the Indicators to provide samples and rubrics for workshop activities in certain sessions.

The Indicators are as follows (Helix et al., 2022): 1. Place the research questions of their laboratory in the context of the larger field and communicate the significance of their specific project to the larger research questions. 2. Justify their experimental design as appropriate for their research question. 3. Analyze and interpret data in order to construct explanations and models that are relevant to their research question. 4. Generate hypotheses and plan future experiments in response to their analysis and interpretation of data and research questions.

Backwards Design

The Backwards Design framework is used to design lessons, modules, and courses in an educational context (Stapleton-Corcoran, 2023). In Backwards Design, what students are expected to be able to learn or do (also known as learning objectives) by the end of a lesson, module, or course is identified. From there, instructors or organizers develop assessments to evaluate that students are indeed learning what they are supposed to. The final step involves creating materials and activities that teach students what they are expected to know and lead into the assessment. Learning objectives, assessments, and teaching materials must be aligned and work in tandem for effective implementation of the Backwards Design framework. This framework was

used to develop teaching plans for scientific content knowledge and lab techniques during the BURET-BOBYUR workshop series.

Ten Salient Practices of Effective Research Mentors

Shanahan et al. (2015) conducted a review of one hundred peer-reviewed articles concerning undergraduate research mentoring to identify ten salient practices of effective research mentors. Each topic in the BURET-BOBYUR Workshop Series featured at least one of the ten salient practices as appropriate. All ten of the salient practices were taught to the workshop participants at one point or another in the workshop series.

The following are the ten salient practices of effective research mentors (Shanahan et al., 2015; Walkington et al., 2019): 1. Do strategic pre-planning in order to be ready to respond to students' varying needs and abilities throughout the research process. 2. Set clear and well-scaffolded expectations for undergraduate researchers. 3. Teach the technical skills, methods, and techniques of conducting research in the discipline. 4. Balance rigorous expectations with emotional support and appropriate personal interest in the student. 5. Build community among groups of undergraduate researchers and mentors, including graduate students, post-doctorals fellows, and any other members of the research team. 6. Dedicate time as well to one-on-one, hands-on mentoring. 7. Increase student ownership of the research over time. 8. Support student's professional development through networking and explaining norms of the discipline. 9. Create intentional, ladder opportunities for peers and "near peers" to learn mentoring skills and to bring larger numbers of undergraduates into scholarly opportunities. 10. Encourage students to share their findings and provide guidance on how to do so effectively in oral and poster presentations in writing.

Coaching for Research Teaching and Mentoring Using K-12 Educator Training Approaches

Many approaches have been used to "coach" (meaning here to instruct or train someone on a specific action or task directly over the course of 1 on 1 interactions) teachers who must teach a pupil to learn something that is of interest to the pupil or learn something that is required by other external forces (Ali, Wahi, & Yamat, 2018; Knight, 2009; Showers, 1985; Stormont et al., 2015; Veenman & Denessen, 2001). Several approaches have also been used to coach individuals on how to be an effective mentor in various contexts for a variety of reasons (Fletcher & Mullen, 2012; Garvey, Strokes, Megginson, 2010; Lancer, Clutterback, & Megginson, 2016; MacLennan, 2017; Maritz & Visagie, 2011; Sorkness et al., 2017). STEM Research contexts are slightly more complicated than other scenarios since there is a heavy focus in teaching various elements necessary to complete a research project, but also to mentor researchers so that they grow and develop to be part of the academic and scientific communities as suited to their goals and motivations (Coté, 2024; Shanahan, 2015; Titus & Ballou, 2013). A common scenario in the research context is that a graduate student or post-doctoral scholar is tasked with serving in two different, but united roles (Aikens et al., 2016; Ann Mabrouk & Gapud Remijan, 2023; Coté, 2024; Dolan & Johnson, 2010):

1) A *teacher* to an undergraduate student researcher who needs to learn about and how to carry out a research project. 2) A *mentor* to an undergraduate student researcher that is invested in the growth and success of the undergraduate student over the course of the research collaboration.

This interplay between teaching and mentoring is significant and any intervention that is focused on training these graduate students or post-doctoral scholars to support undergraduate students should be wary of that. In the previous sections of this chapter and in the section following this one, we will describe frameworks and design rationale respectively for our training intervention in this context, the BURET-BOBYUR Workshop Series. However, the workshop is structured to be similar to a course since we allow a cohort of 30 participants to attend. Under this format, there are some aspects of training of teaching and mentoring (See the previous *Background* sections in this chapter) that are difficult to include without dedicated 1 on 1 interactions. Therefore, to complement the BURET-BOBYUR Workshop series, we were interested in designing and incorporating dedicated 1 on 1 coaching sessions to help improve and enhance a mentor's approach to teaching and mentoring of undergraduate researchers.

We note that there is little literature that focuses on coaching graduate student or post-doctoral scholar research mentors to teach and mentor undergraduate students participating in UREs. However, there is another context where an individual is expected to both effectively teach and mentor a student on a regular basis: K-12 Education. This is quite convenient as many of the teaching and mentoring practices used to support students in K-12 education are also applicable in UREs. The CalTeach program at UC Berkeley is a program where undergraduate students can study pedagogy and become a credentialed K-12 teacher while majoring in a STEM program of their choosing. In CalTeach, a video analysis protocol that was based on other training protocols commonly used for K-12 teachers and university faculty development was implemented (Center for Education Policy Research, 2015; Short and Echevarria, 1999; Tran and Halversen, 2019) to support their student's development.

The video analysis protocol consists of three steps: (1) formulate a focus question about their implementation of a teaching practice to anchor an evidence-based discussion, (2) share the video with peers in a facilitated discussion for feedback on the focus question, and (3) write a post-reflection on what they learned from the discussion and what actionable steps they will take toward improving mentoring. In this study, we will adapt this video analysis protocol to be compatible with the BURET-BOBYUR Workshop Series and for university research labs for our coaching sessions. The materials used for the coaching session and the coaching session design for our study is explained further in the *Methods* section of this chapter.

Workshop Topics and Goals

In the BURET-BOBYUR workshop series, we had 4 main goals. The first goal was to incorporate the theoretical frameworks for teaching and mentoring of undergraduate researchers into a format that could serve as effective training for graduate students. Based on these frameworks, prior research into the BURET project (Coté, 2024; Helix et al., 2022; Krim et al., 2019), and feedback from students who participated in past iterations of BURET-BOBYUR, we arrived at ten workshop topics.

Two topics were covered in each of the five sessions of BURET-BOBYUR over the course of several weeks in the summer. Scheduling was designed so that the topics would take place during each point in a summer URE where the content would be most relevant to a graduate student mentoring an undergraduate mentee. For example, the topic on communication strategies is covered in the beginning of the series in the beginning of the summer while the topic on preparing for undergraduate poster presentations is covered in a session later in the summer.

The second goal was to provide graduate student mentors with an actionable plan to foster their undergraduate student's independence in the research project over the summer. We sought to accomplish this by having the participants "learn by doing," meaning that they would be actively engaged both in and out of the workshop with planning or using the teaching and mentoring practices that were covered. The third goal was to have the graduate student mentors reflect on and evaluate the teaching and mentoring practices they already use so that they can be more effective in their implementations. The fourth goal centered on providing space for graduate student mentors to develop additional teaching and mentoring practices that they can integrate cohesively into other occupations or contexts other than the research lab. The research study procedure that we outline later in this chapter involves a closer investigation into the first and third goals.

In the following subsections, we briefly cover the workshop content and activities for each topic. These topics are organized based on the order they appeared in the BURET-BOBYUR workshop series. More information on the scheduling, preparation, and general program for each workshop is provided in *BURET-BOBYUR Workshop Series Preparation and Program* in the *Methods* section of this chapter.

Developing Questioning Strategies for Communication with Your Undergraduate Researcher

In the first topic of BURET-BOBYUR, we provided an overview of our goals for the workshop series and the general structure of each session. We introduced some of the theoretical frameworks that we used to develop the workshop materials such as the "Ten Salient Practices of Undergraduate Research Mentors" (Shanahan et al., 2015; Walkington et al., 2019), and "Indicators for Integration of Scientific Practices and Content" (Helix et al., 2022). See the *Theoretical and Other Frameworks* section in this chapter for more information. Afterwards, we covered the roles of the mentor and mentee in research, which included the importance of establishing an effective communication strategy and system with undergraduate mentees. To develop an effective communication strategy that participants could try with their mentees, the activity for this topic had the participants in small groups draft and discuss approaches to establishing clear communication and questioning strategies for their mentees, based on their current level of experience with research mentoring. The homework for this topic involved participants drafting a set of questions to probe their mentee's fundamental knowledge for the research project. They were then tasked to share how their mentees responded and how they would address any uncertainties in the coming weeks.

Equity, Access, and Inclusivity in STEM: Accounting for ‘Sense of Belonging’

This topic focused on introducing more concrete strategies to both personalize mentoring and support all undergraduate mentees, while acknowledging each student's unique background, learning styles, mentorship preferences and lived experiences. Participants were given the opportunity to think about the goals they had for their mentees, and we encouraged the participants to recalibrate them based on their compatibility with the mentee's goals, the mentee's familiarity with discipline norms, the mentee's current research ability, and the scientific network they may have access to in the lab. We also sought to encourage mentors to, over time, promote and incorporate the mentee as a full-fledged member of the research lab with a sense of belonging and independence.

We emphasized that promoting equity, access, and inclusivity is an essential component for preparing students to meet their long-term academic and professional goals. Equity, access, and inclusivity can counter several factors that have been known to inhibit student success in STEM and limit their full potentials (Stachl et al., 2021). These factors include lack of representation (which makes it more difficult for students to find positive role models to identify with), microaggressions (which create hurdles for students from historically excluded communities based on preconceptions on who a typical scientist should be), the hidden curriculum (which is a set of unspoken “rules”, skills, and norms in a given STEM discipline that make it difficult for students to navigate the field and lead to feelings of alienation) and imposter syndrome (which is a psychological state where students doubt their belonging, achievements, or ability despite the contrary) (Pender et al., 2010; Santiago & Einarson, 1998; Stachl & Baranger, 2020; Stachl et al., 2021).

The activity for this topic had participants brainstorm with each other methods to foster a sense of belonging in their research labs. Sense of belonging is defined as the extent to which a person believes that they are accepted and seen as a legitimate member of an academic community where their contributions are valuable (Good, Rattan, & Dweck, 2012; Lewis et al., 2016; London et al., 2011; Stachl & Baranger, 2020). Sense of belonging has been shown to be a predictor for student success across various studies (Freeman, Anderman, & Jensen, 2007; Inzlicht & Good, 2006; Stachl & Baranger, 2020; Walton & Cohen, 2011) so we found it imperative to have students engage with it during the activity in this topic. For homework, participants were asked to share an action they took after the workshop to help cultivate a sense of belonging for their undergraduate mentees.

Developing a Teaching Plan

This topic focused on establishing a process through which workshop participants can develop a teaching plan they can apply with undergraduate mentees for broader research elements and to foster mentee independence in research. For teaching plans, we emphasized alignment with the mentee's goals and to be mindful of established communication style and research expectations. We introduced “Progression of Learning” in this topic (Duschl et al., 2011), which is that undergraduate students will start a research project as a “novice” where they are still learning basic

concepts, terms, and lab skills for their research project. Over time and with effective teaching and mentoring, the undergraduate student will move towards being an “expert” which means they are more capable of drawing from more strands of knowledge to create deeper connections between them to guide their thinking and understanding of the project. We instructed the workshop participants to identify where their undergraduate mentee’s knowledge was at and to describe what knowledge would require a teaching plan to facilitate progression of learning for the topic’s activity. In their homework assignment, they were tasked with drafting an outline of a teaching plan for their undergraduate mentees based on what is needed to be an “expert” in the project and the mentee’s current experience level.

Using the CREATE Method for Primary Literature

We shared and explored using the CREATE method in this workshop topic. The CREATE method is an approach for reading primary scientific literature adapted by Dr. Christine Stachl from Hoskins et al., 2007. CREATE is composed of several steps that can be repeatedly used to scaffold and make more accessible primary literature for undergraduate students who are still in the process of gaining mastery and climbing to an expert level of understanding for a research project. The steps are as follows: **C**onsider defining key terms and create logical links between them, **R**ead Methods and Results sections to form conceptual links between the experiment and data collected, **E**lucidate hypotheses by working backwards to define the hypotheses tested in the paper, **A**nalyze and interpret data, and **T**hink of the next **E**xperiment by discussing and debating next experiments.

The introduction to the CREATE method was followed up with several examples from the workshop team. Participants learned from these examples and went through the different steps of CREATE in the activity using a paper that is important for their mentee’s research project that they brought in with them to the workshop session. Afterward, students reflected in small groups on how learning from primary scientific literature with CREATE is different from how they may have learned to read primary scientific literature. Undergraduate mentees engaged with CREATE as facilitated by their research mentors in the workshop as part of this topic’s homework assignment. Workshop participants were also asked to describe in detail how using CREATE went for them in their homework submissions.

Analyzing Student Understanding: Data Analyses

In this topic, we built upon the knowledge assessment techniques we covered in the first workshop to hone the ability of undergraduate mentees to execute experiments and to interpret results from their data. We discussed the knowledge integration framework (Linn & Eylon, 2011; Linn, 1995; Linn, 2000; Songer & Linn, 1991) in this topic to make the participants aware of the processes that undergraduate students typically use to learn in UREs. To review, the knowledge integration framework suggests that students learn by examining ideas they already had, exploring and adding additional ideas, and reorganizing these ideas into a new integrated understanding of a phenomenon. Participants were given 4 samples of undergraduates describing their

research project and had to assess their knowledge of design choices and data interpretation based on evaluation rubrics that were handed out and designed with the knowledge integration in mind. Later, for their homework, participants were asked to use these rubrics with their undergraduate mentees.

Expanding our Teaching Plan to Teach and Assess a Technique or Experiment

Here, we expanded upon the teaching plan we began in a previous topic and focused on expanding it to teach and/or assess a lab technique, scientific theory, or experimental protocol. We provided participants with another approach they could use to create a teaching plan in the form of the “Backwards Design Framework” (Stapleton-Corcoran, 2023). Backwards Design in teaching involves identifying the overall learning goal or teaching objectives of interest, developing a method to assess whether or not those learning goals or objectives are being met, and then creating learning activities or materials that can be evaluated through the assessment. In this topic, members of the workshop team provided numerous examples and anecdotes on prior teaching plans they have created for their undergraduate mentees so that workshop participants could have more ideas for what to implement in their research mentoring. For this topic’s activity, participants filled out a template of their teaching plan using Backwards Design and for their homework they were asked to apply their teaching plans on their chosen lab technique, scientific theory, or experimental protocol and write in detail about how they felt the teaching went and what was or wasn’t helpful for their undergraduate mentees. They were also asked to share in the homework which areas their undergraduate mentees were struggling or which areas their undergraduate mentees were improving from the beginning of the summer.

Developing a Persuasive Teaching Philosophy Statement for Future Job Searches

One of the goals of the BURET-BOBYUR workshop series was to help the participants develop their experience with teaching and mentoring other students that they can use for other professional opportunities outside of the research lab such as a Teaching Philosophy Statement that is commonly required for STEM teaching positions in higher education. The Teaching Philosophy Statement is a description of the author’s idea of how to teach students. It also conveys the author’s pedagogical skills and experience. Participants reviewed samples of statements from past workshop participants in the activity and then they drafted a few paragraphs of their own statements for discussion and reflection amongst themselves. Participants were asked to complete their statements and share with the workshop team for their homework assignment.

Teaching Undergraduates to Communicate about their Research Project through the Creation of an Elevator Pitch

In this topic, we recommended that the workshop participants help their undergraduate mentees develop and practice an elevator pitch for their research

projects. Elevator pitches are an effective method to assess student knowledge, to build scientific communication ability, to provide avenues for scientific networking opportunities, and to help them reflect on the unique contributions of their research to their disciplines. In the presentation for this topic, we reviewed the general components of an elevator pitch and framing the elevator pitch as a short narrative that can be tailored towards different purposes and audiences. We also mentioned strategies to make elevator pitches more interesting and mentioned common pitfalls to avoid such as an overabundance of technical jargon or exaggerating details of the research. Participants drafted and performed their own elevator pitches in their small groups in the activity and they were tasked with writing about their undergraduate mentee's elevator pitch in the homework.

Assessing Understanding Through a Poster Presentation: Experimental Design and Next Steps

It is common in many UREs for undergraduate students to present a research project at the end of the experience. Many of our participants were in the position of guiding their mentees to build a research poster by this point in the summer so this topic served as an overview for how to effectively support mentees in that endeavor. We reviewed the “Indicators for Integration of Scientific Practice/Content” (Helix et al., 2022). We then suggested several methods for how to design a research poster with their undergraduate mentees which included Backwards Design (Stapleton-Corcoran, 2023) and developing evaluation rubric on individual research components similar to the session on evaluating data analysis understanding. We covered several probing questions that workshop participants could use while their undergraduate mentee is practicing a presentation to help their communication of scientific knowledge. For the activity portion of the session, we had the participants score transcripts from student poster presentations that were obtained from previous work in the BURET project (Helix et al., 2022), using an evaluation rubric. They compared and discussed their scores with other participants as well.

Synthesizing Strategies for Teaching and Mentoring Researchers in Current and Future Work

The final topic of the BURET-BOBYUR workshop series involved having the workshop participants reflect on how they grew as teachers and mentors over the summer and recalibrate their expectations for working with undergraduate mentees based on what they learned throughout the workshop series. During the activity, participants reviewed what they had written in the BURET-BOBYUR Pre-Survey form and discussed amongst themselves whether or not their expectations and goals for undergraduate mentees had changed and what inspired that change.

BURET-BOBYUR Research Study

As mentioned in the previous section, our goal with organizing the BURET-BOBYUR workshop series is to train and facilitate graduate students in our department to implement teaching and mentoring practices to support and develop their undergraduate research mentees. In this study, we created an intervention that consisted of coaching from the instructors of the BURET-BOBYUR Workshop Series. This approach to supporting teaching is based on those frequently used to train K-12 teachers. This coaching intervention enables us to directly observe teaching and mentoring practices from the BURET-BOBYUR workshop series, instead of depending only on self-report by the mentors. Therefore, in this research study, we sought to evaluate which teaching and mentoring practices from the BURET-BOBYUR workshop series were utilized by the mentors (See the first research question in the *Background* sections) and the effectiveness of mentors in implementing these teaching and mentoring practices (See the second research question in the *Background* sections).

Evaluation was carried out through a scoring rubric that measures how strongly mentors nurture their mentees to be scientists across several teaching and mentoring practice categories. This evaluation rubric was called: The **BURET Nurturing Aspiring Scientists Evaluation Rubric** (BURET-NASER). Additionally, we sought to identify which and to what extent, teaching and mentoring practices from the BURET-BOBYUR series and coaching sessions would be applied by the participants in their research labs via The **BURET-Coaching of Teaching and Mentoring Instrument** (BURET-CoTaM) (See 1st research question in the *Background* sections). More information regarding the development of BURET-NASER and BURET-CoTaM can be found in the *Methods* section.

Methods

Study Sampling and Recruitment

Graduate students and post-doctoral scholars were recruited for the summer BURET-BOBYUR workshop series via an email invitation sent out to various STEM departments at our institution in the preceding spring semester. In the email invitation, there was an application form that asked applicants about their departments, the research labs that they were working in, a brief description of their research projects, and whether or not they have ever worked with an undergraduate student in a research setting. In addition, applicants were also asked to indicate their availability for specific workshops, if they planned to work with an undergraduate student over the summer in a research project, and their general goals for participating in the BURET-BOBYUR workshop series.

These questions were used to filter and select a cohort of workshop participants from the applicants. Each iteration of the BURET-BOBYUR workshop series targeted a cohort size of about thirty individuals. Priority for admission to BURET-BOBYUR was given to applicants who were expecting to mentor an undergraduate student during the

workshop series and participants from the chemistry department. Accepted applicants were informed via email and given two weeks to confirm participation.

In the second session of the workshop, the research team invited the cohort to participate in our research study investigating changes in graduate student/post-doctoral scholar teaching and mentoring of undergraduate students during research experiences. An overview was provided of what the research study entailed and what the commitments would be from the study participants. Recruitment for the research study itself took place in the 3rd Workshop. Graduate student/post-doctoral scholar mentors and their undergraduate students were given the option to either sign physical or digital consent forms to confirm participation. Our study procedures were approved by the University of California, Berkeley Committee for Protection of Human Subjects, Protocol #2016-02-8360.

BURET-BOBYUR Workshop Series Preparation and Program

Approximately, one month prior to the beginning of the first session of the workshop series, members of the research team held a meeting to discuss logistics for the workshop, scheduling of sessions, preparation and launch of the workshop's course website, team member responsibilities, room locations, and organization of the workshop topics. About two weeks before the first session in the workshop series, accepted participants were invited to the course website. On the website, participants were asked to complete the Workshop Pre-Survey to provide the workshop team with more information about their goals for participating in BURET-BOBYUR, prior experience with mentorship of undergraduate students, and what ideas they had for mentorship practices with their mentees that summer. The Workshop Pre-Survey can be found in full in the *Appendices*. The course website was where communications to the participants outside of the workshop series occurred. In addition, the course website also hosted announcements, workshop materials, homework submissions, and other useful files.

Each BURET-BOBYUR workshop session followed a similar agenda. First, participants were provided with food and drinks. Participants were organized into small groups based on various criteria depending on the workshop content. After a short warm-up discussion question, the workshop team members that were leading the presentation summarized the goals of the session, shared interesting homework responses to the cohort, and pointed out avenues through which participant feedback in the exit tickets would be implemented going forward. The presenters would then proceed with the first workshop topic of the session.

As mentioned in the *Workshop Topics* section above, there were a total of ten topics in BURET-BOBYUR that were covered over the course of five sessions. Each topic began with a short presentation on the relevant teaching and mentoring practices that were to be covered in the session, a summary of the literature that provides a theoretical foundation for said practices, examples of the implementation of said practices from members of the workshop team, and an introduction to new science education concepts/theories that would help to formulate a plan of action that participants could take and apply outside the workshop session. Next, participants would engage with an activity within their groups where they could draft and share ideas

on how to support their undergraduate mentees with the content featured in the workshop topic. Lastly, groups were encouraged to share out to the whole cohort and take additional notes. Additional information about workshop content and activities can be found in the *Workshop Topics* section of this chapter.

At the end of the second topic of each workshop session, students were asked to complete an exit ticket. The exit ticket asked students to describe what they took away from the workshop, what they planned to implement with their mentees, and suggestions for how to improve future workshops. Lastly, students were assigned homework, typically in the form of a writing assignment, that was posted on the course website. The homework assignments were developed to encourage participants to apply what the teaching and mentoring practices they learned in the workshop into their labs.

In between workshop sessions, the workshop team held meetings to discuss how the most recent workshop session went and to plan for the next workshop session. The workshop team paced the BURET-BOBYUR workshop series so that there would be two to three weeks between workshop sessions. This was done so that participants would have enough time to reflect on or apply the workshop content and to complete their homework assignments.

After the end of the final session in the series, participants with a satisfactory and majority completion/attendance of BURET-BOBYUR were provided with a certificate of completion. All participants in attendance were also asked to complete a final workshop exit ticket and a post-workshop evaluation form that can be used to refine future iterations of BURET-BOBYUR. A copy of this exit ticket and post-workshop evaluation along with a set of participant responses can be found in the *Appendices*.

Study Compensation

Graduate student/post-doctoral scholar mentors who participated in the study and completed all required commitments (provide at least two research mentoring videos and written reflections about those videos, participate in at least two coaching sessions with a member of the research team, and complete an interview) were compensated with a \$200 gift card. Undergraduate students who participated in the study and completed all required commitments (participate in at least two research mentoring videos and complete an interview) were compensated with a \$50 gift card.

Study Population

There were nine pairs of mentors and undergraduate mentees from the BURET-BOBYUR workshop series that offered to participate in the research study. After some discussions were had with the research team and after reviewing the level of commitment of each of the pairs, we narrowed the final sample of the study to five pairs. Priority was given to pairs of students who were able and likely to work with the research team for the study over the course of several months. The level of experience that undergraduate mentees in the sample varied from student to student. Four of the research mentors were graduate students (3 in the chemistry program and 1 in the

chemical biology program) and one of the research mentors was a post-doctoral scholar in the chemical biology program.

Video Recording Guidelines for Research Mentors

Once they were recruited and confirmed to participate in the entire study, each mentor-mentee pair was sent a list of recording guidelines (See *Appendices* for the full list). On their own time, each mentor recorded a video of themselves having a research teaching and/or mentoring interaction with their mentees, with the recording guidelines providing some instructions, specifications, and suggestions for the video. To summarize the recording guidelines, mentors were allowed to choose research related interactions that were based on workshop content that they could have with their mentees to film (such as going over a data set, learning a new instrument, providing constructive feedback, assessment of student understanding with open-ended questioning, etc.) as long as it was something that they would have interest in receiving teaching and mentoring coaching from a member of the research team over. Furthermore, the video recording guidelines asked mentors to keep their videos between 10-15 minutes long. In the *Results* section, we provide a table of what type of research interaction each mentor chose to share for each of their video recordings in this study.

Written Reflection Prompt for Research Mentors

Alongside their videos, mentors were asked to write a written reflection. The written reflection was about 1-2 pages long and was an opportunity for mentors to contextualize their videos and describe to the research team their intended goals with the video, what they specifically would like assistance or feedback on, what they thought went well, and what they think could have been improved in the interaction with their mentee. A full breakdown of the written reflection prompt can be found in the *Appendices*. In Table 3.1 below, we outline the main components and context of each video recording that we asked each mentor to share with the research team prior to the team watching the video and organizing the coaching sessions.

Table 3.1: Written Reflection Questions

#	Question Sets
1	Why did you choose this lesson/topic/interaction for your video? Did you have a specific goal in mind? Please give some context for your video.
2	What aspects of this video recording would you like us to provide feedback on?
3	What do you think went well with regards to supporting development of your mentee's understanding of the research project?
4	What would you like to do differently next time?

Coaching Session

Members of the research team reviewed each video recording and written reflection and took extensive notes in preparation for the coaching session. Coaching sessions for each mentor were typically scheduled about 1 week after receiving a set of their materials. A single member of the research team (A.G) would participate in the coaching session with each mentor using a collection of notes from and suggestions from other members of the research team. The structure of the coaching sessions were designed around some of the approaches found in the literature that are used to train instructors in K-12 classrooms. This is because, as described in the *Theoretical and Other Frameworks* section of this chapter, there is overlap in the practices used between training to teach in the classroom and training to teach in the research lab in at least some STEM contexts.

The general structure of each coaching session contained 4 stages. First, was the *Introduction Stage*, where the researcher and the mentor introduced themselves, provided a quick update on how things were going with their mentees, and briefly summarized the materials that were submitted. In the second stage, *Contextualization*, the researcher would ask a set of prepared probing questions about the materials, the mentor's approach, the research project itself, the lab environment, or the mentor's relationship with their mentees to obtain further context that might not have been conveyed in the video recording or the written reflection. The additional context would help the researcher frame or organize the next stage of the coaching session which was the *Coaching Review Stage*. Here, the researcher would share notes, feedback, praise, suggestions, and constructive criticism of teaching and mentoring featured in the video based on their review of the materials which included a compilation of thoughts from other members of the research team. At certain times, the researcher would go in video chronological order for each of their points and would even play clips or provide transcripts of the recording to review with the mentor if appropriate. The mentor would also be provided space to ask follow-up questions or share their input. The final stage, *Mentor Planning*, involved the research mentor planning with the researcher how to incorporate and iterate on their teaching and mentoring based on what was discussed in the coaching session. Ideas were shared between the two on potential applications or scenarios that could help improve teaching and mentoring of mentees in the future. The mentor would also have the opportunity to go back to video recording with the researcher and ask for specific teaching and mentoring feedback on anything of their interest if it was not already touched upon in the earlier stages of the coaching session.

Coaching sessions lasted about thirty to sixty minutes long and took place either in-person or on Zoom depending on the mentor's preferences. All coaching sessions were recorded and transcripts were obtained from them after a proper deidentification process. The mentors were also provided a copy of the coaching session and the transcript for their reference in future research interactions and video recordings. After the completion of a coaching session, the mentors were asked to send another video recording and written reflection within the span of two weeks if they were able to or interested. Additional submission of materials would also lead to another coaching session.

Final Interview Protocol (Mentor and Mentee)

A final interview was conducted with the mentor and mentee (separately) with a member of the research team after they had completed at least two video recordings and two coaching sessions (if they were a mentor). These final interviews had different semi-structured interview protocols for the mentor and the mentee. In the case of the mentor, the interview protocol featured questions on their takeaways from the BURET-BOBYUR workshop series, how they felt the workshop shaped their teaching and mentoring in research, their perspective on what they consider to be teaching and mentoring in research, their personal and academic goals, and feedback on the coaching sessions they experienced.

For the mentees, their interview protocol asked about their motivations for getting involved in research, what they consider to be the most important takeaways from the research experience, how their dynamics with their research mentor changed over time, what specific actions their research mentors took when teaching or mentoring them, how their scientific identities and self-efficacy changed, and if they have a better understanding of research-related work. Interviews lasted about thirty to sixty minutes in duration and all interviews took place over Zoom. Interviews took place about 1 month after the final coaching session was done with each mentor. The interviews were recorded, transcribed, and deidentified by the research team. The protocol used in the mentor or mentee interviews can be found in the *Appendices*. Below, we provide tables of example questions we asked in the mentor and mentee final interviews.

Table 3.2: Examples Questions Asked in Mentor Final Interviews

#	Question
15	From our coaching sessions, was there anything that you would have liked more help with?
16	In what ways were recording research interactions with your undergraduate mentee useful?
17	How did you grow as a teacher and a mentor as a result of study participation and coaching (if at all)?

Table 3.3: Examples Questions Asked in Mentee Final Interviews

#	Question
6	How did participation in research change your impression of being a graduate student or a STEM scientist?
7	What were your impressions of what research would be like before you participated in it?
8	How did your mentor contribute to your expectations of research and being a

	researcher?
9	How would you describe the research dynamic between you and your mentor over the summer?
10	Did that dynamic change over time and in what ways?
11	In general, how did your research mentor teach new concepts, techniques, or protocols for the project?

Data Storage

Data for all submitted materials in this study was stored on a UC Berkeley licensed Box account. The data is deidentified and organized by creating a unique, random codename for each participant. A key was created that links the random code names to identifying data. The key is stored and kept secured on Box separately from the rest of the data. The researchers are the only individuals who have access to identifying data on Box. Data and keys stored on Box are to be deleted 3 years after completion of this study.

BURET-CoTaM Development and Usage

There are several previous studies that have been completed under the BURET umbrella prior to this work (Coté et al., 2026; Coté, 2024; Helix et al., 2022). From those studies, Coté collected and analyzed data from graduate student research mentors of undergraduates students in UREs. This data was compiled alongside what is known about teaching and mentoring practices in UREs in the literature to develop the ***BURET-Teaching and Mentoring Instrument*** (BURET-TaM) (Coté, 2024). BURET-TaM was intended to be an instrument that “distinguished between teaching and mentoring in UREs and CUREs, ensure that the codes were general enough to apply to any STEM discipline, and analyze data and produce a set of teaching and mentoring practices that have been used with undergraduate researchers” (Coté, 2024). Below, we provide more detail on the definitions of URE teaching and mentoring that served as the foundation for BURET-TaM and then provide more detail on the data collected from graduate student research mentors to develop the codes in BURET-TaM.

Coté (2024) utilized definitions of teaching and mentoring in BURET-TaM that were focused on undergraduate students being actively engaged and participating in their respective science during a URE. Teaching in UREs was defined as utilizing teaching practices that have “undergraduate students learn about existing scientific content knowledge, the process of collecting new information through discipline-specific methods, and the generation of new knowledge.” Teaching practices, under that context, should consist of actions and activities that “bring about science learning” (Ambrose et al., 2010; Coté, 2024; Hirst, 1971; National Research Council, 1996). Mentoring in UREs was defined as utilizing mentoring practices that “support the career development and psychosocial development of undergraduate researchers.” Coté (2024) considers mentoring practices to be activities that develop a mentoring

relationship. Mentoring relationships were considered by Coté (2024) and Kram (1983) to have four stages: initiation, cultivation, separation, and redefinition. “Cultivation” in particular, refers to the point in the mentoring relationship (and the URE) where undergraduate students are collaborating with the individual(s) who are responsible for mentoring them in their research project (Coté, 2024; Kram, 1983; Mullen & Klimaitis, 2021). The cultivation stage is of special significance to BURET-TaM as Coté (2024) argues that this is where mentoring relationships begin to feature two types of goals. The first is “Career Development” which include mentoring practices that advance or support a mentee’s career interests. The second is “Psychosocial Development” which include mentoring practices that “address the psychological and social-environmental” of working in a STEM field (Coté, 2024; Ehrich et al., 2004; Fletcher & Mullen, 2012; Kram, 1983).

Coté (2024) and her research collaborators at the time interviewed 45 graduate student research mentors about their experiences working with undergraduate students in a research-related setting. From that interview data and references to the literature regarding scientific inquiry (Duschl, 2003), the Cognitive Dimension (Domains) of Inquiry (Duschl, 2008; Furtak et al., 2012), the Cultivation stage of mentoring relationships (Ceyhan & Tillotson, 2020; Creswell & Poth, 2016; Dolan & Johnson, 2009; Ehrich et al., 2004; Fletcher & Mullen, 2012; Kram, 1983; Shanahan et al., 2015; Walkington et al., 2019), and other work in BURET (Helix et al., 2022; Krim et al., 2019), a series of codes were developed that can be used to identify various teaching and mentoring practices in broad STEM URE contexts among other purposes (Coté, 2024).

In this work, we used BURET-TaM to help identify teaching and mentoring practices within the video recordings that we obtained from our study participants. We adapted the codes somewhat within BURET-TaM to fit the context of our study. However, as feedback and suggestions from coaching sessions with study participants is a critical component of this work, we opted to add three “Coaching” codes to BURET-TaM that were based on changes of teaching and mentoring practices that can be directly tied to what was discussed in the coaching sessions.

The first coaching code was “*Integration*.” This code was used during the video recordings where it was evident that the research mentor was using a teaching or mentoring that was suggested by the research team during a coaching session. Next, was the “*Implementation*” code. This code was used during mentoring videos where we observed the mentor implementing a stated teaching or mentoring goal from their written reflections or coaching session. Lastly, there was the “*Refinement*” code. *Refinement* was used to identify teaching and mentoring practices in the video recordings that were used in a previous video recording, but its use was now improved or refined as a result from suggestions in the Coaching Sessions. This iteration of the instrument was denoted as the **BURET-Coaching for Teaching and Mentoring Instrument** (BURET-CoTaM). See the *Appendices* for the full list of codes for BURET-CoTaM.

BURET-CoTaM was used on each of the 10 video recordings that were collected for this study. A tracking spreadsheet was created to tally and aggregate the teaching, mentoring, and coaching codes used by each member of the research team as they reviewed each video recording. In the *Results* section of this chapter, we provide several tables of these tallies. The teaching, mentoring, and coaching codes from

BURET-CoTaM were also used to conditionally connect to the other instrument in this study, BURET-NASER, which we describe in the next sub-section.

BURET-NASER Development and Usage

To determine the effectiveness of the BURET-BOBYUR Workshop Series and the Coaching Sessions described earlier in this chapter, we were interested in developing an evaluation rubric for the teaching and mentoring practices that we observed in the video recordings. As we outlined in the *Workshop Topics and Goals* section, there was a plethora of activities and teaching and mentoring practices that were covered in the BURET-Workshop Series. Thus, it would not be feasible to develop to try to measure or evaluate every possible teaching and mentoring practice that could occur between a research mentor and their mentor. We decided to focus on a small set of practices for both teaching and mentoring practices. For teaching, these practices were: *Teaching of Fundamental Research Knowledge*, *Teaching of Research Procedures*, *Teaching of Data Analysis*, and *Teaching of Scientific Communication*. For mentoring, these practices were: *Promoting Student Self-Efficacy and Scientific Identity*, *Student Assessment*, and *Support for Post-Graduate Opportunities*. These practices were selected as they were aligned with what was generally emphasized in BURET-BOBYUR and were expected to be relatively common across different research contexts. In the next subsection, we describe each practice (also referred to as Rubric Categories) in more detail and the criteria required for each score level for each category.

A rubric was selected as the form of our evaluation instrument for a couple of reasons. First, we were interested in comparing the implementation of teaching and mentoring practices that research mentors in the study would employ with their mentees in the video recordings before and after a coaching session with members of the BURET-research team. A rubric would enable the research team to compare to what extent a specific teaching and mentoring practice was impacted by participating in the coaching session based on observable data and qualitative analysis of how the practice was executed between video recordings. The second reason lies within rubric scoring. The act of scoring teaching and mentoring practices using the rubric can help demonstrate which (if any) practices our study participants were stronger at using compared to others since many of the mentoring videos took place after workshop installments. This information could be used to tie back into the BURET-BOBYUR Workshop material and improve the instruction in future iterations of the series. It could also be used to establish commonalities with the approaches and experiences of the research mentors in the study to one another despite differences in research projects and mentees.

In the *Background* section of this chapter, we detailed our perspective of what effective teaching and mentoring of undergraduate researchers entails. To summarize, teaching and mentoring in research should have mentors proactively plan to integrate numerous teaching and mentoring practices over the course of a collaboration with an undergraduate student and to use these practices in tandem with one another to aid the mentee's development. Mentors should be prepared to be receptive to their mentees goals, needs, or feedback based on their established dynamic with them and adapt their teaching and mentoring practices accordingly. Our view is that undergraduate

researchers are future members of the scientific community and should be supported as such. Mentors are, in a sense, nurturing the aspiring scientists within their mentees throughout the course of a URE. We carried this mindset into the development and design of our evaluation rubric which we have named the **BURET-Nurturing Aspiring Scientists Evaluation Rubric** (BURET-NASER).

Unlike most of BURET-CoTaM, BURET-NASER was developed entirely for this project. Development of BURET-NASER took place over a three-month period. Members of the research team regularly met during this time to decide on which teaching and mentoring practices would be evaluated, how to describe each category, and what criteria would be used for each level of scoring per category. Over time, consensus was reached on the descriptions and criteria for each category and examples were deliberated on to help distinguish between scoring levels. Further refinement was done after test runs of BURET-NASER. In these test runs, members of the research tried out the rubric on a sample teaching and mentoring video (BURET-CoTaM was also included in these test runs) to see if agreement could be reached on which teaching and mentoring practices to score and on the score itself. Once we had reached acceptable reliability and understanding for using BURET-NASER, we began using it on the video recordings obtained for this study.

Evaluation with BURET-NASER is dependent on information gained from first using BURET-CoTaM. For example, if a video recording contains teaching of fundamental research knowledge and it is coded as such with BURET-CoTaM, then the research team would evaluate that teaching under the *Teaching of Fundamental Research Knowledge* category on BURET-NASER. For a category (teaching or mentoring practice) in BURET-NASER to be used in a video recording, the appropriate practice must first be identified and coded with BURET-CoTaM. Otherwise, the category would not be used for that specific mentoring video (which corresponds to a score of NP). As the research team were using BURET-NASER in the video recordings, scores for each category were tracked in a spreadsheet. A breakdown of scores listed in this spreadsheet is further detailed in the *Results and Appendices* section.

Rubric Categories and Scoring

In this section we provide an overview of the categories and scoring levels for each category in BURET-NASER. The rubric in its entirety is shown below for reference in Figure 3.1.

Figure 3.1: BURET-NASER Instrument

Score	Teaching of Fundamental Research Knowledge	Teaching of Research Procedures	Teaching of Data Analysis	Teaching of Scientific Communication	Promoting Student Self-Efficacy and Scientific Identity	Student Assessment	Support for Post-Grad Opportunities
	<u>Description</u> To be used for mentoring videos relating to teaching of new	<u>Description</u> To be used for mentoring videos relating to teaching of research procedures; which	<u>Description</u> To be used for mentoring videos relating to teaching of data analysis. This includes practices that engage	<u>Description</u> To be used for mentoring videos relating to teaching and practicing scientific communication.	<u>Description</u> To be used for mentoring videos where the mentor is taking steps to promote the student's	<u>Description:</u> To be used for mentoring videos where the research mentor is actively probing the student's	<u>Description</u> To be used for mentoring videos where the mentor and the mentee are discussing or sharing advice

	research concepts, theories, or fundamental knowledge through conversations and/or reading of scientific literature.	includes demonstrations of scientific instruments, research protocols, and/or research skills.	students with science as a body of knowledge such as comparing and contrasting data, discussing experimental data, interpreting data to find meaning, validate theories, etc.	This includes practicing for lab group meetings, creating a research poster presentation, creating arguments using scientific rationale and data, creating visual figures, or writing for a publication.	self-efficacy and/or scientific identity, which could include making the mentee “feel” like a scientist, encouraging the mentee to confidently engage in research.	knowledge on the research project, background knowledge, research context, and significant theories, and following up with assistance if necessary.	on pursuing post-graduate opportunities. Preparing materials for these opportunities are also included.
0	Not applicable or present	Not applicable or present	Not applicable or present	Not applicable or present	Not applicable or present	Not applicable or present	Not applicable or present
1	Briefly mentions background knowledge or research questions with little to no explanation or engagement with mentees. Perhaps makes an assumption on a student's current knowledge level or lacks student assessment.	Research procedures, skills, or techniques for research or explained in a disorganized manner with little active engagement with the mentee. Ex) <i>Mentor gives mentee a procedure and expects them to carry it out without any guidance; or performs procedure “behind the scenes” with no interaction from mentee.</i>	No integration of appropriate instruction between experimental data, data analysis methods, or data interpretation. Mentee is not actively engaged. Ex) <i>Mentor tells the mentee the result or how to interpret something, without going into detail why the data interpretation is made based on the data collected and/or methods used.</i>	One-sided guidance for any type of scientific communication. Or the mentee is either going through the presentation with minimal input from the mentor. Ex) <i>No input given or requested by mentor or mentee. Little discussion on what changes can be made or what to do next.</i>	Mentor does not actively improve mentee self-efficacy and scientific identity.	Does not ask the student or allow the student any opportunity to demonstrate knowledge about the research project or fundamental background knowledge/context/theories. Ex) <i>Mentee talks to their mentor about a research project and the mentor remains silent or passively nods. Does not engage actively in conversation to probe for further understanding</i>	Discussion regarding post-graduate opportunities does not take place or the mentor does not answer questions related to post-graduate opportunities.
2	Partial or vague explanation of fundamental knowledge, and/or concepts related to the research project. Does not connect background knowledge to the	Mentor explains and performs research procedures as mentee observes (shadowing)	Minimal integration of appropriate instruction between experimental data, data analysis methods, or data interpretation. Mentee is engaged at the “bare minimum” level.	Practicing of scientific communication includes a small amount of collaboration between the mentor and the mentee for how to enhance the communication. Ex) <i>Some suggestions for what to say or how to phrase</i>	Mentor promotes student's self-efficacy and/or scientific identity with positive reinforcement on actions they have taken or insights they have gained in research. Ex) <i>“Good job on this task”</i>	Lightly challenges or assesses the student on the research project or fundamental background knowledge/context/theories and provides minimal assistance to the student if appropriate.	Mentor asks the mentee about their plans after undergrad and/or responds to questions about opportunities after undergrad. Mentor gives information as asked by the mentee. The

	research project, goals, or research motivations. Ex) Yeah. Well, there's a specific type of steric interaction that when it's in the axial position, it interacts in a...? 1,3 diaxial interaction. As drawn – and that's also, we got to fix that – You can't have something in the axial position on this carbon that's pointed down. Wait, I'm tripping!"		Ex) Mentor explains how to interpret data based on previous data sets or by comparing and contrasting collected pieces of data.	certain material is present or how to explain important figures. There is some visible uncertainty on how to communicate the research or on what to change in the material.	"This was a difficult task but you handled it well" "I think your progress on your presentation is coming along great" "We didn't get what we wanted, but you carried out the procedure perfectly, sometimes things just don't work out"	Ex) The mentor asks some questions (clarifying/basic questions) but does not ask challenging questions or assess students' knowledge beyond the current research context . If the student struggles, the mentor provides minimal assistance to the student. "Do you know how to do this? Did you get that?"	answer is very self contained in the conversation and is not scaffolded based on how familiar the mentee is with how the appropriate ecosystems work Ex) This may include discussion with the undergrad in trying to figure out what they want to do if they are uncertain.
3	Satisfactory explanation of fundamental knowledge and/ or concepts related to the research questions. Minimal connection of this knowledge to the goals or motivations of the research project. Does not assume prior knowledge of the student. Students may be engaged in the instruction (contextual).	Mentor guides mentee through research procedures as they engage with it. As in, mentee is the one physically carrying out the procedure and the mentor is not directly helping with the procedure. Mentor could be providing them with either instruction or advice. Both mentor and mentee could be considered to be on "auto pilot."	Thorough integration of appropriate instruction between experimental data, data analysis methods, or data interpretation. Mentee is actively engaged during instruction. Exchange of ideas on how to analyze data with a clear explanation of how data is analyzed in science. Ex) Right, if we wanted to compare this data against, say, nickel iron at one molar KOH, we can basically add	Scientific communication involved a moderate amount of cooperation, input, and effort from both the mentor and mentee when preparing or practicing materials. Each member is given space to share their inputs on the appropriate approach for the research project. There is some mutual understanding and agreement on what comes next.	Mentor promotes the student's self-efficacy and/or scientific identity through positive reinforcement and/or reassurance towards mentee's uncertainty regarding their work. Alternatively, mentor praises mentee on their work (with a specific comment) and gives them encouragement for future tasks Ex) Mentee: "I don't know if I did this correctly" Mentor: "You did this right I like how you used X"	Meticulously challenges or assesses student knowledge on the research project or fundamental background knowledge/context/theories and provides help when the student struggles. Ex) Challenges the student's knowledge / procedural skills by engaging in more sophisticated conversation/discourse with the student about the overarching concepts related to the procedure.	Mentor does what is described at level 2 and provides resources concerning post-graduate opportunities, such as fliers, job fair information, or gives advice concerning graduate school. Mentor attempts to scaffold information for post-graduate opportunities, but information may not be fully organized/comprehensive based on the student's needs.

	Ex) “The goal itself was always to just obtain our energy for our ion transfer reaction. We’re explicitly doing this because originally with our analysis, we were looking at different methods using a slightly different model. But then we found that it became less stable. So then we use this program now to see if we can accurately depict ion transfer.”		another two columns and copy paste that data, and it would be pretty easy if you just like to add onto it. For example, you can insert two columns. Now let’s go back, and one more thing we should add is just in the comments. You can write what the parameters were for this experiment, especially in terms of what is our independent variable in this, in this entire test?		<i>Mentee: “I don’t think my presentation is very good”</i> <i>Mentor: “I think it’s a good start, we can work on it and figure out ways to improve it”</i> <i>Mentee: “I think I did something wrong, my reaction didn’t come out as expected”</i> <i>Mentor: “Sometimes things just don’t work correctly, walk me through your steps and we can try finding the issues together”</i>	“So how would you approach “x” if “Y” happened?” Do you know why we do “x”? “In what situations would we want to implement “X?”	
4	Outstanding explanation of fundamental knowledge and/ or concepts related to the research questions. Clear connection of this knowledge to the goals or motivations of the research project. Does not assume prior knowledge of the student. Students are actively engaged in the instruction (contextual). Ex) “We	Mentee performs procedure and explains their reasoning as mentor supervises and facilitates learning. Mentor steps in when asked but otherwise lets the mentee freely execute procedures if the mentee demonstrates adequate understanding of the procedure.		Evident that mentor and mentee came to a clear, comprehensive, and shared understanding on what should be done for scientific communication. Mentor and mentee spent an appropriate amount of time sharing and listening to each other’s perspective on the current state of the presentation in-depth and what they think could be done to improve the presentation (contextual).	Mentor promotes the student’s self-efficacy and/or scientific identity through positive reinforcement and/or reassurance towards mentee’s uncertainty regarding their work. Mentor also provides support when mentee is expressing self-doubt. Mentor can help mentee by sharing their experiences of them learning or by sharing the mindset they used to overcome obstacles. Alternatively, mentor praises mentee on their work and gives		Mentor does what is described in Levels 2 and 3. Mentor is also active in helping mentee with the process of preparing for post-graduate opportunities. Such as proofreading personal statements, helping make resumes, practice interviews, etc. Or the mentor gives high level wisdom/advice about the struggles of post-graduate opportunities, what the experience is like, etc. in addition to doing things from Levels 2

were looking for three things in terms of energy. #1 was the hydroxide ion. #2 was the explicit waters, which is very – It says H_2O_n, so the amount that we use could vary. Afterwards we're going to find our product, which is the hydroxide shrouded with the explicit waters. Number two, specifically, finding the energy, we can go on for as long as we want [for] geometric optimization. It explicitly said in the video that we only use one job for the hydroxide ion, but then we can use as many jobs as we want for the explicit waters. At what point does the energy plateau to where we can figure out how much water we need? Typically, because these jobs are really costly, we want to optimize the amount of jobs we can do. So, we				them encouragement for their future career. Ex) Mentee: "I don't feel like I am capable of doing this" Mentor: "I have worked with you for a while now and I know you can. And if you do run into any trouble I'll be around to help out" Mentee: "I'm not good at this. I am really slow in carrying out these steps" Mentor: "That's okay, speed isn't the goal here. The important part is carrying them out correctly which you are doing" Mentee: "I don't think I am built for this" Mentor: "This doesn't come easy to anyone and everyone starts from the bottom. Just give it your best shot and then we can work together to improve from there."		and 3. Mentor scaffolds information, giving out information regarding post-grad opportunities in a way that is proactive, comprehensive, and not overwhelming. The degree of information given out is natural and appropriate for the student.
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want an amount that's a little bit and still consistent with the energy."						
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In BURET-NASER, each category (column) represents a teaching or mentoring practice that we were interested in evaluating along with the different scoring levels. The first of these was the *Teaching of Fundamental Research Knowledge* category. To be scored under this category, the mentor in the video recording must be clearly trying to teach some important or essential aspect of the research project to the mentee, such as theories, background knowledge, or project motivations to the mentee. As we argue that effective teaching and mentoring of undergraduate students necessitates that teaching work in synergy with other practices (if applicable), be part of a conscious and scaffolded plan, and accommodate the mentee's goals and needs, we scored this category based on how prepared and sophisticated the mentor was at the instruction and engaging the mentee as an active learner.

The next category was titled *Teaching of Research Procedures*. This category was used for videos that featured the mentor teaching a research protocol, instrument, or technique to the mentee. We used a similar thought process as the previous category for how to consider the "scale" of scores for this category and for how to distinguish different scoring levels (this will be the case for the remaining categories as well). The slight change for this category was that we focused more on how well the mentor was actively engaging the mentee in the instruction or demonstration.

The third category, *Teaching of Data Analysis*, was for videos that contained teaching of data analysis. Comparing and contrasting data sets, exploring how scientific knowledge is generated, and validating theories/hypotheses with data is also valid for this category. Scoring levels here were distinguished by mentee engagement and how clear the connection between the analysis and the rest of the project was.

The last teaching practice was the *Teaching of Scientific Communication* category. Any mentoring videos that featured the mentor teaching communication skills or norms to the mentee were scored under this category. In addition, videos that were about practicing with the mentee for a poster, oral, or slideshow presentation were also included here. The scoring levels here emphasized frequent and thoughtful collaboration between the mentor and mentee, meaning that each member was able to contribute ideas or provide feedback on the material to be communicated.

The first mentoring category was *Promoting Student Self-Efficacy and Identity*. We used this category in the case of mentors that were taking steps to cultivate the student's self-efficacy for the research project and/or their scientific identities. Such steps could take the form of making the mentee "feel like a scientist", general psychosocial support, or promoting the mentee's confidence to succeed in the research project. The unique component for the scoring of this category was looking to see if there was repeated, positive reinforcement of the mentee's achievements or growth throughout the interaction.

In the *Student Assessment* category, we evaluated the extent to which the mentors were able to assess the student's understanding of context sensitive research aspects in the video. This could include any of the subjects of the teaching practices that were a part of BURET-NASER or next steps for the research project. Scoring was decided based on how intricate and "deep" the assessment was in the video.

The final mentoring practice featured in the rubric was the *Support for Post-Graduate Opportunities* category. This category aims to evaluate any videos where the mentor is providing advice, insight, or assistance for the mentee to engage in relevant post-graduate opportunities. In this category, the level of scoring is determined by how much scaffolding of support there is on this subject matter. For example, at a lower score, the mentor may only briefly mention a post-graduate opportunity. Then at the next level, they would increase the amount of support they provide. At the highest level, a mentor may mention a post-graduate opportunity, then connect it to the mentee's interests, then provide advice for how to get involved with said opportunity, then directly help the mentee when they take steps to engage with the opportunity.

Limitations

We recognize selection bias as one limitation in this project. Selection bias in this context refers to the event where certain students are more likely to be present and selected to participate in the BURET-BOBYUR Workshop series and/or the research study itself due to having more established academic networks or from having already participated in other teaching or mentoring training initiatives. In addition, participants might be more prone to being involved with pedagogical development than their peers. The act of recording a video of a research interaction may also have a slight influence on authenticity as mentors may portray "idealized" versions of their teaching and mentoring. We attempted to control for this by providing flexible instructions that would facilitate the most authentic interaction possible in the videos and we also provided encouragement towards authenticity in the coaching sessions. We do not claim or argue that participating in the BURET-BOBYUR Workshop Series was the only factor that has contributed to the development of the teaching and mentoring outcomes that we report in this study. However, we do argue that participation in the coaching sessions had an observable impact on the effectiveness of undergraduate teaching and mentoring in UREs based on our collected data.

Results

Three members of the research team (A.G., X.C., & K. N.) reviewed the mentoring videos and written reflections for each of the five mentors who participated in this study. The five mentors were given the code names of *Red*, *Gold*, *Ruby*, *Diamond*, and *Sun*, respectively. Afterwards, each member used the BURET-CoTaM and BURET-NASER instruments for the video recordings and written reflections as described in the *Methods* section. In-between the review of the first and second videos for each mentor, the researchers also reviewed the recording of the coaching sessions that were completed in the middle of the research study timeline. BURET-CoTaM was used here to qualitatively analyze the main takeaways from each coaching session and

how they would manifest in the second video recordings. Below, in Figure 3.2, we summarize the subject of the research interaction that took place in all of the video recordings that we obtained.

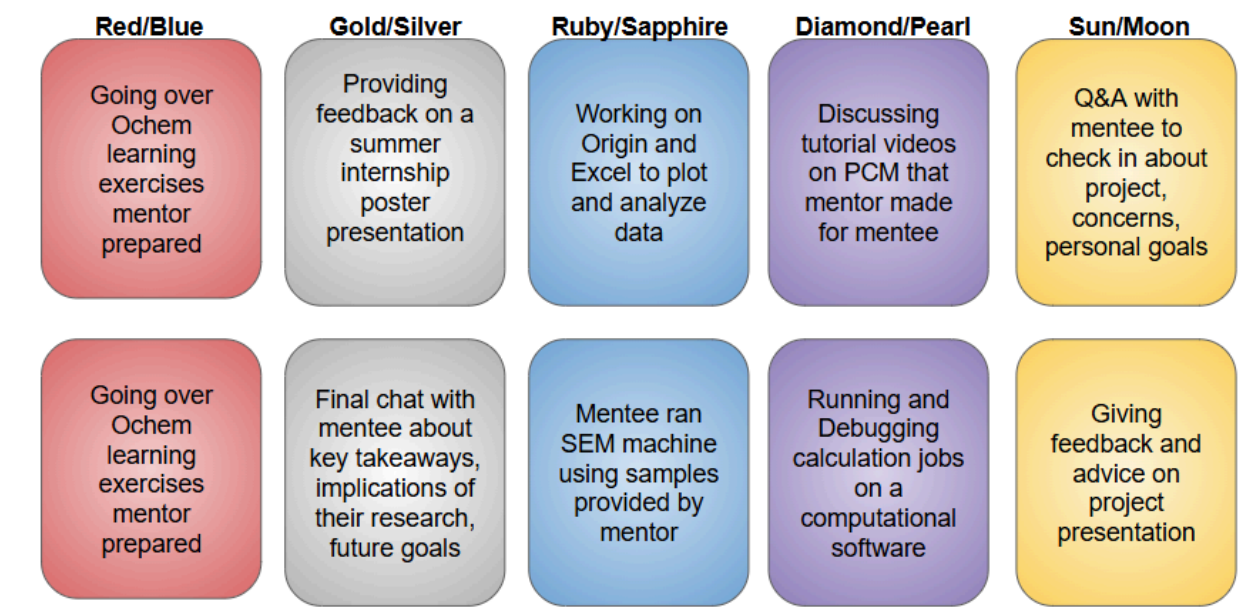


Figure 3.2: Summary of Research Interactions Featured in Mentor's First (Top) and Second (Bottom) Video Recordings

As is apparent in Figure 3.2, there was a wide range of different types of research teaching or research mentoring interactions that we were able to observe in this study. The three members of the research team kept track and compiled their codes and scores for BURET-CoTaM and BURET-NASER respectively in a dedicated tracking spreadsheet. We have split up the codes that each researcher used for BURET-CoTaM into three tables below (Tables 3.4, 3.5, and 3.6) per mentoring video. Table 3.4 lists the codes used for the Teaching Category, Table 3.5 lists the codes used for the Mentoring Category, and Table 3.6 lists the codes used for the Coaching Codes. A "PRESENT" value in the table indicates that the researcher applied that code in a specific video recording while a "ABSENT" value indicates the opposite. The tables are color-coded by video recording and by the researchers for convenience and reference.

Table 3.4: Overview of CoTaM Selections for Teaching Codes by Researcher and Video

Mentor Video	Researcher	Teaching of Fundamental Research Knowledge	Teaching of Research Procedures	Teaching of Data Analysis and Interpretation	Teaching of Scientific Communication	Stated Teaching Goal Present	Mentor-Mentee Engagement Through Teaching
Red 1	A.G.	PRESENT	ABSENT	ABSENT	ABSENT	ABSENT	PRESENT
	X.C.	PRESENT	ABSENT	ABSENT	ABSENT	ABSENT	PRESENT
	K.N.	PRESENT	ABSENT	ABSENT	ABSENT	ABSENT	PRESENT
	A.G.	PRESENT	ABSENT	ABSENT	ABSENT	PRESENT	PRESENT

Red 2

	X.C.	PRESENT	ABSENT	ABSENT	ABSENT	ABSENT	PRESENT
	K.N.	PRESENT	ABSENT	ABSENT	ABSENT	PRESENT	PRESENT
Gold 1	A.G.	PRESENT	ABSENT	ABSENT	PRESENT	ABSENT	ABSENT
	X.C.	PRESENT	ABSENT	ABSENT	PRESENT	ABSENT	PRESENT
	K.N.	PRESENT	ABSENT	ABSENT	PRESENT	ABSENT	ABSENT
Gold 2	A.G.	ABSENT	ABSENT	ABSENT	ABSENT	ABSENT	ABSENT
	X.C.	ABSENT	ABSENT	ABSENT	ABSENT	ABSENT	PRESENT
	K.N.	ABSENT	ABSENT	ABSENT	ABSENT	ABSENT	ABSENT
Ruby 1	A.G.	PRESENT	ABSENT	PRESENT	ABSENT	ABSENT	PRESENT
	X.C.	ABSENT	ABSENT	PRESENT	PRESENT	ABSENT	PRESENT
	K.N.	ABSENT	ABSENT	PRESENT	PRESENT	ABSENT	PRESENT
Ruby 2	A.G.	ABSENT	PRESENT	ABSENT	ABSENT	PRESENT	PRESENT
	X.C.	ABSENT	PRESENT	ABSENT	ABSENT	ABSENT	PRESENT
	K.N.	ABSENT	PRESENT	ABSENT	ABSENT	PRESENT	PRESENT
Diamond 1	A.G.	PRESENT	PRESENT	PRESENT	PRESENT	PRESENT	PRESENT
	X.C.	PRESENT	ABSENT	PRESENT	PRESENT	PRESENT	PRESENT
	K.N.	PRESENT	ABSENT	PRESENT	PRESENT	PRESENT	PRESENT
Diamond 2	A.G.	ABSENT	PRESENT	PRESENT	ABSENT	PRESENT	PRESENT
	X.C.	ABSENT	PRESENT	PRESENT	ABSENT	PRESENT	PRESENT
	K.N.	ABSENT	PRESENT	ABSENT	ABSENT	PRESENT	PRESENT
Sun 1	A.G.	ABSENT	PRESENT	ABSENT	ABSENT	ABSENT	ABSENT
	X.C.	ABSENT	ABSENT	ABSENT	ABSENT	ABSENT	ABSENT
	K.N.	ABSENT	ABSENT	ABSENT	ABSENT	ABSENT	ABSENT
Sun 2	A.G.	ABSENT	ABSENT	ABSENT	PRESENT	ABSENT	PRESENT
	X.C.	ABSENT	ABSENT	ABSENT	PRESENT	ABSENT	PRESENT
	K.N.	ABSENT	ABSENT	ABSENT	PRESENT	ABSENT	PRESENT

Table 3.5: Overview of CoTaM Selections for Mentoring Codes by Researcher and Video

Mentor Video	Researcher	Establishing Mentoring Dynamic	Fostering Research Independence	Helping Mentee Career Development	Providing Psychosocial Support	Stated Mentoring Goal Present	Mentor-Mentee Engagement Through Mentoring
Red 1	A.G.	ABSENT	ABSENT	ABSENT	PRESENT	ABSENT	ABSENT
	X.C.	ABSENT	ABSENT	ABSENT	PRESENT	ABSENT	ABSENT
	K.N.	ABSENT	ABSENT	ABSENT	PRESENT	ABSENT	ABSENT
Red 2	A.G.	ABSENT	ABSENT	ABSENT	PRESENT	ABSENT	ABSENT
	X.C.	ABSENT	ABSENT	ABSENT	PRESENT	ABSENT	ABSENT
	K.N.	ABSENT	ABSENT	ABSENT	PRESENT	ABSENT	ABSENT
Gold 1	A.G.	ABSENT	ABSENT	ABSENT	ABSENT	PRESENT	ABSENT

Gold 1

	X.C.	ABSENT	ABSENT	ABSENT	ABSENT	ABSENT	ABSENT
	K.N.	ABSENT	ABSENT	ABSENT	ABSENT	ABSENT	ABSENT
Gold 2	A.G.	ABSENT	ABSENT	PRESENT	PRESENT	ABSENT	PRESENT
	X.C.	ABSENT	PRESENT	PRESENT	ABSENT	ABSENT	ABSENT
	K.N.	ABSENT	ABSENT	PRESENT	PRESENT	PRESENT	PRESENT
Ruby 1	A.G.	ABSENT	ABSENT	ABSENT	PRESENT	ABSENT	ABSENT
	X.C.	ABSENT	ABSENT	ABSENT	ABSENT	ABSENT	ABSENT
	K.N.	ABSENT	PRESENT	ABSENT	ABSENT	ABSENT	ABSENT
Ruby 2	A.G.	ABSENT	PRESENT	ABSENT	ABSENT	ABSENT	ABSENT
	X.C.	ABSENT	ABSENT	ABSENT	ABSENT	ABSENT	ABSENT
	K.N.	ABSENT	ABSENT	ABSENT	ABSENT	ABSENT	ABSENT
Diamond 1	A.G.	ABSENT	PRESENT	ABSENT	PRESENT	ABSENT	PRESENT
	X.C.	ABSENT	ABSENT	ABSENT	ABSENT	ABSENT	ABSENT
	K.N.	ABSENT	ABSENT	ABSENT	ABSENT	ABSENT	ABSENT
Diamond 2	A.G.	ABSENT	ABSENT	ABSENT	ABSENT	ABSENT	ABSENT
	X.C.	ABSENT	ABSENT	ABSENT	ABSENT	ABSENT	ABSENT
	K.N.	ABSENT	ABSENT	ABSENT	ABSENT	ABSENT	ABSENT
Sun 1	A.G.	PRESENT	PRESENT	PRESENT	PRESENT	ABSENT	ABSENT
	X.C.	ABSENT	ABSENT	PRESENT	PRESENT	ABSENT	PRESENT
	K.N.	PRESENT	ABSENT	PRESENT	PRESENT	PRESENT	PRESENT
Sun 2	A.G.	ABSENT	ABSENT	ABSENT	PRESENT	PRESENT	ABSENT
	X.C.	PRESENT	ABSENT	ABSENT	PRESENT	ABSENT	PRESENT
	K.N.	PRESENT	ABSENT	ABSENT	PRESENT	PRESENT	PRESENT

Table 3.6: Overview of CoTaM Selections for Coaching Codes by Researcher and Video

Mentor Video	Researcher	Coaching - Integration of Feedback	Coaching - Implementation of Stated Goal or Approach	Coaching - Refinement of Previously Used Practice
Red 2	A.G.	PRESENT	PRESENT	PRESENT
	X.C.	PRESENT	ABSENT	ABSENT
	K.N.	ABSENT	PRESENT	ABSENT
Gold 2	A.G.	PRESENT	PRESENT	ABSENT
	X.C.	PRESENT	ABSENT	ABSENT
	K.N.	PRESENT	PRESENT	ABSENT
Ruby 2	A.G.	PRESENT	ABSENT	ABSENT
	X.C.	PRESENT	ABSENT	ABSENT
	K.N.	PRESENT	PRESENT	ABSENT
Diamond 2	A.G.	PRESENT	ABSENT	ABSENT
	X.C.	PRESENT	ABSENT	ABSENT
	K.N.	PRESENT	PRESENT	ABSENT

Sun 2	A.G.	PRESENT	PRESENT	ABSENT
	X.C.	PRESENT	PRESENT	ABSENT
	K.N.	PRESENT	PRESENT	ABSENT

Next, we aggregated the codes used with BURET-CoTaM in a few different ways. This was done so that we can check for the consistency of code frequency between researchers across the different video recordings and to determine observable patterns in how the researchers coded different sets of videos. In Table 3.7, we tallied the total frequency of CoTaM codes by researcher for all ten video recordings.

Table 3.7: Aggregated CoTaM Code Selections by Researcher for All Videos

Researcher	Total Number of Teaching, Mentoring, or Coaching Codes in CoTaM that were Identified in All Videos
A.G	52
X.C.	48
K.N.	40
Total	140

In the following Table 3.8, we break down and sum up the total number of CoTaM codes (regardless of category) used by all researchers for each of the mentors (meaning both videos the mentors submitted were combined). We split this aggregation of codes by specific mentor video in Table 3.9.

Table 3.8: Total Number of Teaching, Mentoring, and Coaching Codes in CoTaM used by All Researchers Sorted by Mentor

Mentor	Total Number of Teaching, Mentoring, or Coaching Codes in CoTaM that were Identified in All Videos by All Researchers
Red	25
Gold	23
Ruby	24
Diamond	34
Sun	34

Table 3.9: Total Number of Teaching, Mentoring, and Coaching Codes in CoTaM used by All Researchers Sorted by Mentor Video

Mentor Video	Total Number of Teaching, Mentoring, or Coaching Codes in CoTaM that were Identified by All Researchers
Red 1	9
Red 2	16
Gold 1	8
Gold 2	15
Ruby 1	11
Ruby 2	13
Diamond 1	19
Diamond 2	15
Sun 1	14
Sun 2	20

The BURET-NASER Scores that each researcher provided to each video recording is compiled into Table 3.10 below. Lastly, from the final interviews with the mentors and the mentees that participated in this study, we were able to identify some interesting findings that we use to support and contextualize our data from BURET-CoTaM and BURET-NASER (See *Discussion* section of this chapter). The research team gathered this support by discussing together and coming to a consensus on how each mentor felt about their experience with the coaching sessions and reflecting on their collaboration with their undergraduate mentee in the mentor interviews. For the mentee interviews, we discussed and reached a consensus for each one for their thoughts on how they grew as a researcher over the summer and what actions their mentor took to support their growth in the URE.

Table 3.10: BURET-NASER Scores by Researcher and Video

Researcher	Video	Teaching of Fundament Knowledge Score	Teaching of Research Pro. Score	Teaching of Data Analysis Score	Teaching of Scientific Comm Score	Promoting Student Self-Eff. and Scientific Identity Score	Student Assessment Score	Support for PostGrad Opport. Score
A.G.	Red Video 1	2	0	0	0	1	2	1
A.G.	Red Video 2	3	0	0	0	0	2	0

X.C.	Red Video 1	2	0	0	0	1	2	0
X.C.	Red Video 2	2	0	0	0	0	2	0
K.N.	Red Video 1	2	0	0	0	1	2	0
K.N.	Red Video 2	2	0	0	0	0	2	0
A.G.	Gold Video 1	2	0	0	2	1	1	1
A.G.	Gold Video 2	0	0	0	0	2	0	4
X.C.	Gold Video 1	2	0	0	2	0	1	0
X.C.	Gold Video 2	0	0	0	0	0	2	4
K.N.	Gold Video 1	2	0	0	2	1	1	0
K.N.	Gold Video 2	0	0	0	0	2	0	4
A.G.	Ruby Video 1	1	0	3	0	2	2	0
A.G.	Ruby Video 2	0	3	3	0	0	2	0
X.C.	Ruby Video 1	0	0	3	1	0	2	0
X.C.	Ruby Video 2	0	3	0	0	0	2	0
K.N.	Ruby Video 1	0	0	3	1	0	2	0
K.N.	Ruby Video 2	0	3	0	0	0	2	0
A.G.	Diamond Video 1	4	1	1	0	1	3	0
A.G.	Diamond Video 2	0	4	2	0	0	3	0
X.C.	Diamond Video 1	4	0	2	0	0	3	0
X.C.	Diamond Video 2	0	4	2	0	0	3	0
K.N.	Diamond Video 1	4	0	2	0	0	3	0
K.N.	Diamond Video 2	0	3	2	0	0	3	0
A.G.	Sun Video 1	0	0	0	0	4	3	3
A.G.	Sun Video 2	0	0	0	2	4	3	0

X.C.	Sun Video 1	0	0	0	0	4	2	4
X.C.	Sun Video 2	0	0	0	2	4	3	0
K.N	Sun Video 1	0	0	0	0	4	2	4
K.N.	Sun Video 2	0	0	0	2	4	3	0

Discussion

What Aspects of the BURET-BOBYUR Workshop Series Translate Undergraduate Teaching and Mentoring in UREs?

From using BURET-CoTaM on the first set of video recordings and written reflections of each research mentor, we observed that four out of five videos featured the teaching practice *Teaching of Fundamental Research Knowledge*. This should not be too surprising of an observation as the first set of videos was recorded close to the beginning of the BURET-BOBYUR Workshop Series, so it is possible that the topic focused on creating a Teaching Plan was fresh on the minds of the mentors. However, a finding of interest related to this teaching practice lies in how it integrated with other teaching and mentoring practices more so than any other teaching practice. Mentors who spent time teaching fundamental research knowledge also tended to use *Teaching of Scientific Communication*, *Student Assessment*, and *Promoting Student Self-Efficacy and Scientific Identity*. We observed in the mentoring videos that mentors would try to actively engage mentees when they were being taught a new fundamental aspect of the research project and offer reassurance or acknowledgement depending on their current level of understanding. This specific combination of practices were emphasized in the BURET-BOBYUR Workshop Series to be used together in the provided examples and activity discussions.

Another component of the BURET-BOBYUR Workshop Series that appeared in the submitted materials was that mentors were quite reflective and goal-orientated about research teaching and mentoring during coaching sessions. We focused on that approach in the first workshop session and it was interesting to see it carry over outside the workshop. Interestingly, we note that after coaching sessions, the spread of teaching and mentoring practices changed in the subsequent video. The second video for most of the mentors featured a different type of interaction compared to the first one and sometimes the teaching and mentoring practices that were in the first video would not be present in the second.

The impact of the BURET-BOBYUR Workshop Series was also exhibited in the week to week experience of the undergraduate mentees that collaborated with the cohort of mentors that participated in the series. While only a handful of these mentees participated in the study, the ones that we interviewed indicated that their mentors helped to “humanize” the research experience. For reference, the five mentees were given the code names *Blue*, *Silver*, *Sapphire*, *Pearl*, and *Moon* respectively. In Silver’s interview, they mentioned that their mentor (Gold) changed their expectations on what

to do research and to be a scientist which was a mentoring practice that the mentors engaged with early in the BURET-BOBYUR Workshop Series.

*My expectations of being like a researcher or a **scientist was like day in day out, all you do is experiments.** All you do is this. That's all you do as a researcher. But she kind of showed me that there's more than that*

Likewise, Pearl's mentor (Diamond) changed their preconceptions of graduate student mentors being harsh or too demanding of their students.

*He's just a very calm, upstanding dude. And I think I've definitely heard **horror stories about people's, like, grad students getting mad at them** or frustrated about everything, but he kind of.... Whether it's this project, whether it's like his past work, whether it's like him as a person, he's shown me that not everything in research goes right, but that's okay as long as you just keep doing it, that's all that matters.*

When asked in their interviews, which part of the BURET-BOBYUR Workshop Series was most useful to them, mentors replied with the topic that centered on establishing effective communication, goals, and expectations. An example of this sentiment is provided below from Ruby's interview.

I think starting off in the **beginning of the summer** with kind of **setting expectations with my mentee**, that was definitely the most helpful because I realized that she wasn't necessarily interested in- I mean, she is, but her priority wasn't, you know, publishing a paper or going to conferences.

Diamond expressed the same sentiment and added that inclusivity can help boost the mentor's confidence level.

*I think the most important takeaway I got, which really helped me, is creating barrierless **communication**. And then how inclusivity really affects mentors like confidence level.*

There exist some interesting patterns in the BURET-CoTaM data. First, is that the members of the research team (A.G and X.C) with more experience studying and investigating undergraduate teaching and mentoring in UREs tended to use more codes in the video recordings. It is possible that having more experience with this subject matter would increase the "ability to see and distinguish" between teaching and mentoring practices which would then lead to more BURET-CoTaM codes being used. One of the members of the research team (A.G) was also directly involved in leading the workshop over the summer which could leave an impression on what to observe using BURET-CoTaM. Another pattern is that the research mentors (Diamond and Sun) that had prior experience (meaning before participating in the summer BURET-BOBYUR Workshop series) working with undergraduate researchers tended to have more BURET-CoTaM codes used in their videos than those who were experiencing it for the first time. From analyzing their responses to the BURET-Workshop Pre-Survey Form, we believe that the mentors with prior experience were able to draw upon teaching and mentoring practices they had already had in their repertoire and supplemented those with the practices taught in the BURET-BOBYUR Workshop Series and in the coaching sessions which could be one explanation for this higher code count.

Overall, the BURET-BOBYUR Workshop Series succeeded in helping the mentors in the study strategize and plan for a "nurturing" approach when it came to supporting their mentees in their research laboratories. The mentors became more

reflective about improving in their roles and were more comfortable talking about effective teaching and mentoring of undergraduate students. Meanwhile, their mentees were appreciative of the time spent clearly establishing expectations, goals, and the work environment over the summer.

Can Researcher-led Coaching Sessions with Research Mentors from BURET-BOBYUR Enhance or Complement their Teaching and Mentoring Practices for Supporting Undergraduate Students in UREs?

For the most part, coaching sessions focused on improving or adding mentoring practices. Mentors rarely asked for feedback or assistance with improving or implementing teaching practices to their current approach. The research member who hosted the coaching sessions attempted to be balanced between providing feedback on the teaching and mentoring practices they observed, but it was clear that most mentors were more interested in improving their research mentoring compared to teaching. The BURET-BOBYUR Workshop Series also tried to strike a balance between topics relating to teaching and mentoring in research so this emphasis on mentoring was notable to the research team.

The focus on mentoring practices continued even to the final interviews of some of the mentors. First, Ruby shares one important takeaway from her coaching sessions where she reflected on a discussion had there about how much independence was appropriate to give to her mentee, Sapphire, at that point in the summer URE.

Yeah. I think maybe in the first feedback session, there was, I think you mentioned like maybe taking some more time or like letting them have some more time to think and answer a question or like just letting them have some of that like silence. Thinking time. I think I tried to do that a little bit more over time where I'll just ask her a question and if she's still thinking about it, I'll kind of...I don't want to feel like I'm staring at her, waiting for an answer. With her, I'll start walking around and it'll give her some time to maybe collect her thoughts because I'm not expecting an answer, or I'll try to maybe give her a hint, so giving her more of a chance to figure it out on her own.

Sun describes how they enjoyed the format of the coaching sessions and how it made it more comfortable to discuss their teaching and mentoring approach. Sun also mentions how the coaching sessions helped them to see how to support students from different perspectives or approaches and how to see the value in adapting their approach. In general, all research mentors reported that they felt the coaching sessions were helpful to them.

You know, I really liked the whole semi-in-time nature of [the coaching sessions]. Just two people, like a research meeting, getting together and talking about what they are struggling with and getting the outside opinions on it. And being able to come here with a particular ask and then getting your advice and input on it was super-duper helpful. I really like that. Having the materials to go back and look at is cool... I feel like the meetings were actually really helpful especially with giving me direction or advice on how to approach certain things because I'm completely myopic and not being able to see things the way you can with your outside perspective. So [coaching sessions] were really helpful.

The coaching sessions also helped to alleviate uncertainties or concerns that research mentors had regarding the effectiveness of their undergraduate mentoring. Some mentors expressed doubts about their ability to be an effective mentor. In these cases, the researcher would provide some psychosocial support and positive reinforcement to ensure that the mentor would continue to improve their teaching and mentoring approach to their undergraduate mentee. This would later manifest in the

second video that each mentor provided and in the second coaching session. We observed that the mentors were much more confident and comfortable working with and supporting their mentee in whatever the subject of their video was.

Teaching practices that appeared in the videos would differ between the first and second video for most of the mentors. This makes comparing teaching practices before and after the first coaching session a little difficult. If a mentor utilized the same teaching practice in both videos, members of the research team tended to score them at about the same level on BURET-NASER. Mentoring practices however, were more likely to be present in both videos across the set of mentors we studied and members of the research team tended to score them a bit higher on BURET-NASER. This aligns well with what was typically emphasized in the coaching sessions.

BURET-NASER scores tended to be similar among different members of the research team. The combination of video recordings, written reflections, coaching sessions, and final interviews were very helpful in contextualizing each interaction. This made it easy for the research team to have consistent scores for each video. This is a welcomed outcome for our study as different members of the research team have different experience levels and backgrounds when it comes to analyzing teaching and mentoring practices. Coaching sessions, in particular, were helpful in scoring the second set of videos as we were able to more easily distinguish between scoring levels for each category based on knowing the “intent” for the teaching and mentoring approach as outlined in the session. The coaching sessions may also have had influence on the code frequency for BURET-CoTaM as well. We report that every mentor (except for Diamond) had more teaching and mentoring practices identified via BURET-CoTaM after the coaching sessions (within their second video recordings). While some of this increase is due to the coaching codes now being applicable to these second set of video recordings, we did indeed see a wider range of teaching and mentoring practices being used in the videos post-coaching session.

Refinement of BURET-CoTaM and BURET-NASER Instruments

Overall, we found the instruments that were used in this study to be accessible and easy to use for this data. During practice runs and actual evaluation of the research data, the research team generally were in agreement with identifying practices and scoring them with the instruments. The research team was also consistent with respect to being able to distinguish between different scoring levels on BURET-NASER. Differences in scores or marks can be attributed to the different level of experience between the research team on being able to “see” what teaching or mentoring can look like in a research lab.

For BURET-CoTaM, there is room to expand the codes in it to identify additional ways that mentors could support students or ways that the coaching could impact undergraduate teaching and mentoring. Recall that we did not include every practice that was featured in the BURET-BOBYUR Workshop series so it is possible to check for more practices. Coaching codes could be made to be more specific towards achieving the goals indicated by the research mentor in the workshop series.

For BURET-NASER, we propose that it would be more impactful of an instrument if mentors were able to be coached more frequently in the study and for longer

durations. To get the most information from the rubric scores, it would be beneficial if the coaching sessions were able to focus on improving a specific set of teaching and mentoring practices. This could lead to more comparisons across coaching sessions and thus, more evidence towards their effectiveness.

For both instruments, we must find additional methods for accommodating different levels of mentoring experience in the study sample. Also, the instruments should be able to control or acknowledge the presence of other external factors that occur throughout a URE that could influence (either positively or negatively) teaching and mentoring. We did not make the claim in this work that the BURET-BOBYOUR Workshop Series or the coaching sessions are the sole contributors for the improvements and positive outcomes seen in the different research mentors' approach towards supporting their undergraduate mentees.

Recommendations

The BURET-BOBYUR workshop series provided a large quantity of insights into how the teaching and mentoring practices that were covered would be translated by STEM research mentors over the course of a summer URE. In the Fall 2025 semester, shortly after the conclusion of the 2025 BURET-BOBYUR Workshop Series, we had the opportunity to collaborate with the Discovery Research Hub at UC Berkeley to adapt the workshop series (minus the coaching sessions) over the course of the academic school year and for an audience that includes both STEM and non-STEM research mentors.

The Discovery Research Hub is an interdisciplinary fellowship piloted by the Center for Interdisciplinary Critical Inquiry and the Kavli Energy Nanoscience Institute that pairs Discovery Fellows (graduate student or post-doctoral scholar research mentors) with Discovery Scholars (undergraduate students) to conduct research together during the academic year. They are paired together based on program and pairs or grouped together into “research clusters” where they can build a community in the fellowship. Discovery Fellows are expected to work closely with and provide mentorship to the Discovery Scholars. The Discovery Fellows and Scholars are required to participate in several activities and complete deliverables that show research progress. In particular, Discovery Fellows are expected to attend workshops that cover training for how to be a research mentor.

The BURET team assisted with the development of these training workshops. We adapted the BURET-BOBYUR Workshop Series content and activities to be more inclusive for non-STEM research mentors in the form of additional mentoring examples during activities and a pivot away from more STEM loaded terminology. In addition, this adaptation of BURET-BOBYUR included connections to the other curriculum that was covered in other events by the Discovery Research Hub such as the end of year Discovery Research Symposium. Instead of workshop sessions being separated by a few weeks, the BURET-BOBYUR Workshop Series was held once a month throughout the academic year.

Outside of those changes, the general format, list of topics, and frameworks that were already in the summer iteration of the BURET-BOBYUR Workshop Series remained the same. As in the summer iteration, participants were provided an opportunity to evaluate and provide feedback at the end of the workshops. From the

gathered evaluations, we received largely positive receptions and a myriad of supportive comments from the Discovery Fellows. This experience has highlighted to the BURET research team that BURET-BOBYUR can be effective and translate well to other timetables and audiences. Therefore, we recommend that individuals or institutions who are interested in pursuing an initiative to provide teaching and mentorship training to graduate students or post-doctoral scholars in their programs consider implementing a workshop series that is inclusive and actively engages participants such as the BURET-BOBYUR Workshop Series.

The coaching sessions that we piloted in this study demonstrated potential for further increasing the effectiveness of mentoring practices employed by mentors in UREs and increased the frequency of teaching and mentoring practices that would be used. Our study attempted to balance performing these coaching sessions in a relatively controlled fashion while also giving the mentor flexibility to share what they wanted help with or to steer the direction of the coaching session itself. While this led to an authentic view into the teaching and mentoring between a research mentor and their undergraduate mentee, it created challenges for instrument development and data interpretation as we tried to be considerate and accommodating of every pair's circumstances and experience levels. It is recommended that future studies or those using a similar methodology consider focusing on a specific set of teaching and mentoring practices for coaching and improvement. This way, it would guarantee that researchers would be able to have a more clear comparison of mentor improvement (or lack of improvement) before and after a coaching session. We also recommend providing more resources and investment into the coaching session itself should one be interested in implementing coaching for their research mentoring training programs. For example, in this study we only held two coaching sessions with the mentors within the span of a couple weeks due to scheduling circumstances and other research responsibilities. Ideally, we would have been interested in hosting more coaching sessions at a more frequent rate throughout the summer to obtain more data and more opportunities to utilize BURET-CoTaM and BURET-NASER. Lastly, we recommend that there be more explicit connections between the training program (whether it be a workshop series or something else) and the coaching intervention. We believe that there could be interesting insights to gain from mentioning in the training program examples of successful improvement of teaching or mentoring from the coaching sessions with other members of the workshop cohort.

Conclusions and Future Work

In this work, we described the development and execution of a novel approach to coaching graduate student mentors to support graduate student or post-doctoral research mentors on several teaching and mentoring practices they could use to support their undergraduate students that participated in a summer URE. After a workshop series that was designed to introduce and have students apply strategies for teaching and mentoring undergraduate student researchers, graduate students were offered the opportunity to receive 1 on 1 coaching sessions with a member of the research team to help with their undergraduate teaching and mentoring through a collaborative, reflective review and discussion of video recordings and written reflections

of research-related interactions they had with their student in the lab. The teaching and mentoring practices observed in these video recordings were evaluated with two instruments (BURET-CoTaM and BURET-NASER) to identify what aspects of the training from the workshop series was being successfully implemented into actual practice and to determine the effectiveness and value of the coaching sessions themselves. The two instruments proved to be well-suited for the purposes of this study and the research team found the instruments to be convenient and fairly accessible. We found that research mentors were able to translate many of the teaching and mentoring practices they learned from the BURET-BOBYUR workshop series in their research lab to support undergraduate mentees and their “teaching and mentoring toolkits” expanded with further experience and coaching. The coaching sessions themselves helped the mentors narrow down on improving specific mentoring practices and grow more confident to be research mentors and role models. The specific format and approach we took for the coaching sessions was well-received by the mentors in this study and we were able to hear from the mentees themselves in interviews that they had positive experiences working with their mentors over the summer. Mentors in the coaching sessions and in interviews also reported that they were able to better reflect on their approach to teaching and mentoring, were able to communicate about it more clearly to others, and were more capable of developing strategies to support students at different stages of a research experience. We validated these findings through final interviews with all of the mentors and mentees who participated in this study. For the future, we will continue to iterate and improve the training in BURET-BOBYUR and place greater emphasis on getting more students involved with coaching with the research team over a greater period of time. The coaching sessions themselves will be expanded based on the feedback we received from study participants. We also plan to offer the BURET-BOBYUR workshop series to a wider range of mentors and mentees in disciplines beyond STEM.

Chapter 3 Contributions

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Appendices

Full Coding Scheme

Implementation of Inquiry Codes

This category focuses on codes about how teachers reflect on their inquiry-based teaching and how they implement/perceive inquiry in their classrooms. Inquiry is defined very broadly - see the II-TG description below.

Table A1.1: Implementation of Inquiry Codes

Code Name	Code Abbreviation	Description
Teaching Practice - Conceptual Domain	TP-DomC	The conceptual domain describes teaching practices / actions that engage students with science as a body of knowledge, including scientific facts, theories, and principles. Examples: Teachers provide students with explicit opportunities to learn about scientific content knowledge.
Teaching Practice - Procedural Domain	TP-DomP	The procedural domain describes teaching practices that utilize the methods of discovery. Examples: Teachers guide students and engage them in hands-on activities for lessons; have students ask questions about the protocols or techniques based on what they know about scientific concepts or principles; have students collect and/or record data; learn the methods and calculations needed to complete activities/assignments; create charts or graphs to represent data visually.
Teaching Practice - Epistemic Domain	TP-DomE	The epistemic domain describes teaching practices that engage students in learning about how scientific knowledge is generated, through their direct involvement with scientific investigation. Examples: Teachers guide students to understand how a particular scientific field generates new knowledge, whether it be through scientific iteration or other experimental modifications, and that this knowledge is subject to change; compare and contrast observations, data, or procedures used in the lesson; interpret data to develop explanations.
Teaching Practice - Social Domain	TP-DomS	The social domain describes teaching practices that engage students in class discussions with group members about the project, research, or work, in a way that allows the student to "work things out," make an argument, or reach a decision. Examples: Teachers guide students to argue or debate scientific ideas; work collaboratively with other group members on the project; and make and participate in class presentations.
Implementation of Inquiry - Challenges	IOI-Ch	The teacher describes unique challenges that have come up trying to incorporate inquiry-based learning. Examples include: Time or Resource Constraints, lack of experience with students and teaching with inquiry, or conflicting teaching habits
Implementation of Inquiry - Observations	IOI-O	Teacher describes ways in which inquiry-based teaching has led to interesting observations about student learning during lessons or interactions with students.
Inquiry Impressions - Student Centered	II-SC	Teachers provide a brief, vague, and/or indistinct impression that their view or understanding of scientific inquiry in K-12 Education centers around facilitating or engaging students to be more independent in their scientific work. Examples include: Teachers describing a preference or proposing changes towards providing students more freedom to explore scientific topics and techniques on their own as opposed to more structured and formulaic "cookbook" lab lessons, teachers mentioning that they want students to think and act more independently, reflecting on previous implementations of inquiry in their class with intention for student independence, or if they share that they think students should engage with scientific inquiry with minimal input from them.
Inquiry Impressions - Authentic Science	II-AS	Teachers provide a brief, vague, and/or indistinct impression that their view or understanding of scientific inquiry in K-12 Education centers around having students emulate authentic scientific investigations/applications/protocols as much as possible in the classroom. Examples include: Mentions from the teacher indicate that they feel inquiry-based teaching is to help students feel more like scientists by drawing connections between practical applications of science to what they do in class, tasking students to use science to solve a real-world problem much like a scientist would do, or having students engage with long/ methodological

		scientific projects.
Inquiry Impressions - Teacher Guided	II-TG	Teachers provide a brief, vague, and/or indistinct impression that their view or understanding of scientific inquiry in K-12 Education centers around connecting student-led scientific investigations to teacher-guided activities, lectures, and/or discussions of scientific content that was covered in class. Examples include: Sharing that students should work in more closed activities or assignments that are focused on mastery of the content, skills, and instruments needed to be an effective scientists, being conscience of and/or implementing NGSS during lessons or lesson planning, or instructing in a manner that would help enable student-led investigations later in class
Teaching Goal	TG	Participants explained their goals, plans, and ideas about teaching practices (these are their goals or plans for the future only, not practices that have already happened.) - they are PLANNING to use this teaching practice.
Teaching Practice Changes	TPC	Teacher describes how their teaching practices have changed as a result of their undergraduate research experiences.
Teaching Assessment	TA	Teacher describes approach for assessing student learning including how students are engaging with scientific inquiry in class.

Scientific Practices Codes

This category contains codes that consist of the science practices, discussions, or connections that mirror those of professional scientists and engineers. Science and engineering practices help to develop student inquiry. Active engagement with science and engineering practices allow students to become more experienced with the nature of scientific investigations. Classroom discussions on how to think, feel, and to perform investigations like a scientist are also key to strengthening student understanding of science. Opportunities to refine student experiments and work provide students with the opportunity to execute a more authentic scientific investigation and help to familiarize them with authentic scientific work in research or industry. This category is focused on identifying these aspects that have been engaged with by students and implemented by teachers in the K-12 classroom.

Table A1.2: Scientific Practices Codes

Code Name	Code Abbreviation	Description
Science and Engineering Practice - Asking Questions and Defining Problems	SEP-AQDP	Asking Questions and Defining Problems - Students formulate questions about their readings, observations, and/or conclusions. Students define a problem to be solved. Questions can also be centered on problem solutions, reasons for problem solving interest, data, experiment design, models, and/or what pieces of evidence are needed to make claims.
Science and Engineering Practice - Developing and Using Models	SEP-DUM	Developing and Using Models - Concrete and/or abstract representations of scientific relationships, features, and systems are used or implemented in class for students to investigate questions, solutions, and/or phenomena of interest.
Science and Engineering Practice - Planning and Carrying Out Investigations	SEP-PCI	Planning and Carrying Out Investigations - Students are provided opportunities to plan and carry out investigations to answer questions and/or solve problems. Investigations may also be carried out to evaluate theories and models with manipulation of variables and experimental conditions. Emphasis is placed on designing investigations that provide evidence or support an investigation or problem to be solved.
Science and Engineering Practice - Analyzing and Interpreting Data	SEP-AID	Analyzing and Interpreting Data - Students are expected to analyze data to identify key relationships between experimental variables, interpret meaning from data, and/or organize data clearly.
Science and Engineering	SEP-MCT	Using Mathematics and Computational Thinking - Applications of Mathematics and Computational Thinking (using logic, patterns, etc.,) are explored in class.

Practice - Using Mathematics and Computational Thinking		Students use Mathematical and Computational Thinking to represent variables, make predictions, and/or to process data. Mathematical Tools and Computer software, simulations, or applications may also be utilized during class.
Science and Engineering Practice - Constructing Explanations and Designing Solutions	SEP-CEDS	Constructing Explanations and Designing Solutions - Students attempt to construct explanations to questions of interest or design solutions to problems they have investigated through reflection of current understandings or interpretations of their experimental results.
Science and Engineering Practice - Engaging in Argument from Evidence	SEP-EAE	Engaging in Argument from Evidence - Implementation of the process of argumentation. Students engage in scientific discussion based on reasoning derived from evidence. Students may also practice engaging/understanding with each other's arguments and scientific evidence to learn how scientists come to agreements and conclusions.
Science and Engineering Practice - Obtaining, Evaluating, and Communicating Information	SEP-OEC	Obtaining, Evaluating, and Communicating Scientific Information - Students read, interpret, and/or produce scientific communications (such as reports, articles, posters, and/or oral presentations). Development of student's ability to communicate their scientific knowledge logically and/or to identify key components of the arguments in the communications of others such as evidence, methodology, question/problem to be addressed, etc. Student learn how to obtain or obtain information that is useful for their own scientific inquiry in databases, libraries, articles, and/or other online sources.
Scientific Refinement Practice - Design Choice Rationale	SRP-DCR	Design Choice Rationale - Students justify their experimental design to themselves and amongst one another during a scientific lesson/project. Students may also provide a clear description of one or more design choices and/or provide rationale that demonstrates understanding of domain-specific content knowledge in the scientific lesson/project.
Scientific Refinement Practice - Design Choice Limitations	SRP-DCL	Design Choice Limitations - Students discuss and understand the limitations of their experimental design in a scientific lesson/project. Students may be asked to clearly identify a limitation that demonstrates domain-specific content knowledge, clearly describe how the limitation may have affected conclusions drawn, and/or clearly propose ways to address the limitation in the future.
Scientific Discussion - Societal Impact/Application	SD-SIA	Societal Impact/Application - Teachers explain and/or have students discuss the practical benefits of their results or contemporary relevance of the classroom lesson, lab, or activity. Should have some scientific connection. Teachers explain and/or have students discuss the societal need to learn about the scientific content in question.
Scientific Discussion - Scientific Fulfillment	SD-SF	Scientific Fulfillment - Teachers motivate students to learn about science or perform scientific investigations for discovery or personal fulfillment during class. Students understand that some science is done to develop our understanding of a subject and not to answer a specific question.
Scientific Discussion - Scientific Context	SD-SC	Scientific Context - Teachers guide or hold discussions with students about the scientific context surrounding the scientific investigation during class. Actions such as having students read into prior experiments, the understanding scientists had of a scientific topic at a given time, evolution of scientific models over time, or learning about the historical figures and techniques that contributed heavily to our current understanding of science are included here.
Scientific Connections - Practices	SC-P	Practices - Teachers observe or describe students making connections between science and engineering practices. Examples include: Using a model to interpret data and choice of computational tools, construction an explanation to a question they had asked, or crafting an argument with evidence so that they can present findings
Scientific Connections - Teamwork	SC-T	Teamwork - Teachers observe or describe students making connections interpersonally to further their work on activities or labs and to further their understanding of scientific content covered in class. Examples include: Asking each other for clarification, cooperating on an experiment to collect data that would be difficult to do solo, or tackling an activity in a more structured and organized way. Students recognize the importance of collaboration in science.
Scientific Connections - Concepts	SC-C	Concepts - Teachers observe or describe students making connections between different concepts covered in class to advance their understanding of a subject. Examples include: Using proton numbers to predict location of elements on the periodic table and therefore, their potential chemical properties. Another example could be using algebraic expressions to understand the shape of curves on graphs or how variables relate to each other.

STEM Mentoring Codes

This category includes codes that relate to the actions or measures that a teacher can do to serve as a STEM Role Model or mentor. Teachers can provide mentoring in terms of STEM development or in terms of providing more emotional support.

Table A1.3: STEM Mentoring Codes

Code Name	Code Abbreviation	Description
Evidence of Mentoring Practice of K-12 Student 1	EMS-1	Evidence of mentoring related to academic/career goals, professional development, (physically doing things related to) entering the scientific community Examples: discussing plans for college or trade schools, provide guidance for pathways for further involvement in STEM, applying for jobs or internships in STEM fields of interest, reaching out to employers or professors (potential advisors); encouraging/supporting student independence as a scientist or professional, related to how prepared they are; doing activities that are characteristic of scientists, taking active steps toward achieving academic or career goals
Evidence of Mentoring Practice of K-12 Student 2	EMS-2	Evidence of mentoring related to psychosocial support, community-building, inclusion, getting to know their mentee better, (self-confidence related to this field) Examples: Encouraging/supporting student confidence as a researcher, scientist, professional, presenter, etc., sense of belonging, nurturing the human side of things; feeling as though you can do those activities that are characteristic of scientists (self-efficacy), "feeling" like a scientist.
Mentoring Practice Changes	MPC	Teacher describes how their mentoring practices have changed as a result of their undergraduate research experiences

Equity Incorporation Codes

Codes in this category are focused on how teachers feel about promoting educational equity in the classroom and the various ways they have tried to do so. In addition, codes focused on incorporating social and racial justice issues in the teaching are also grouped here.

Table A1.4: Equity Incorporation Codes

Code Name	Code Abbreviation	Description
Educational Equity Fostering	EQF	Instances where implementation of the teaching practices or research takeaways contribute to actions or conversations that foster educational equity in the classroom or have raised awareness of issues relating to educational equity. Educational equity is defined as the idea of distributing educational resources and services to students in need such as those from historically underserved students in order to address or compensate for known disparities Special Issue on Diversity and Equity in Science Education (2013). <i>Theory into Practice</i> 52 (1) Equity and Social Justice in Teaching and Science Education. (2012). <i>Teaching and Teacher Education</i> 28
Social or Racial Justice fostering through STEM Learning	SRJ	Discussions or incorporations of social or racial justice with respect to STEM learning in K-12 education. For our purposes, we define social justice as the belief that all citizens in a society should be treated equally in social and legal contexts, have fair access to opportunities and resources, and not be disproportionately affected or marginalized by laws, financial and educational institutions, or inequalities in wealth distribution. Racial justice is defined as the belief that all racial groups should be treated equally and that society should provide equal opportunities to all. Historically marginalized racial groups should be empowered to contribute to racial equality through their lived experiences and anti-racist sentiments should be normalized to help achieve racial equality.
Barriers to Equity Incorporation - (STEM	BEI- (SC, LA, PC)	Teachers point out barriers to promoting educational equity in their classrooms. In particular, teachers mention that they feel restricted to promote equity or to have discussion about it due to the STEM content/curricula they teach (SC), that they don't feel qualified to talk about issues or incorporating educational equity due to either lack of knowledge, experience, or training (LA), or to

Content, Lack of Authority, Potential Conflict)		avoid conflict with individuals or their educational institutions (PC)
Barriers to Equity Incorporation - Other	BEI-O	Teachers point to barriers to promoting educational equity in their classrooms that are not listed here.
Educational Equity Assessment	EEA	The teacher reflects on prior action or discussion about educational equity and identifies an aspect they can improve on.

Insights from Research Codes

The codes in this category focus on any and all insights, skills, values, or beliefs related to teaching that teachers gained from their research experience whether it be through an REU or a research methods course. Takeaways could include changes in teaching practices that were picked up, increased STEM discipline knowledge, more confidence to teach in the STEM subject, experience with scientific investigations that can be passed on to K-12 students, changes in mentoring styles, realizations about the limitations of K-12 science teaching, effectiveness of research experience, or impactful findings/outcomes.

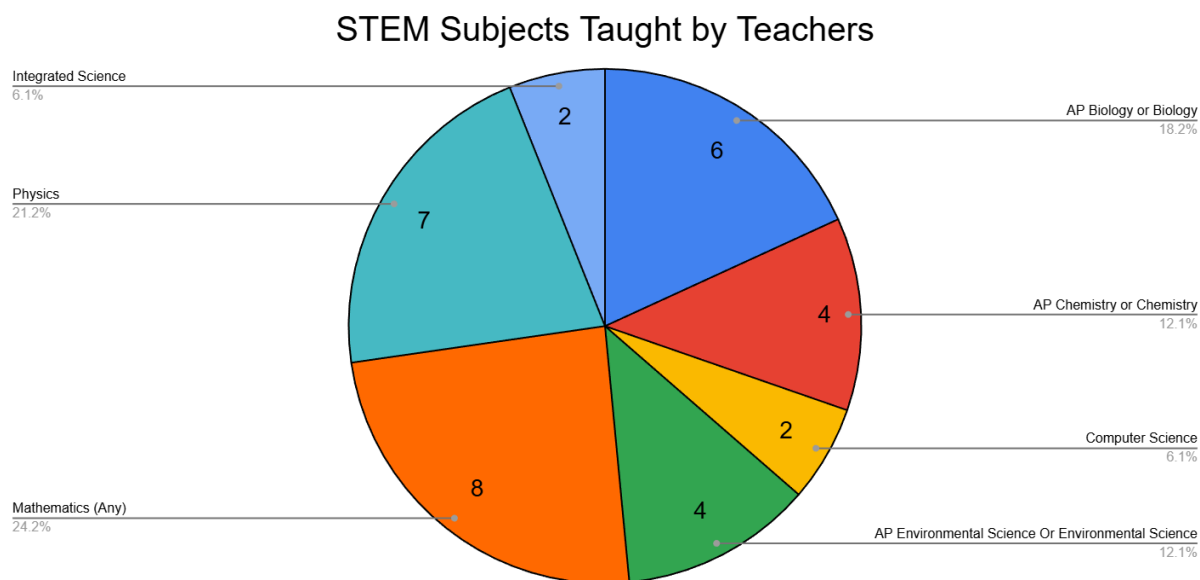
Table A1.5: Insights from Research Codes

Code Name	Code Abbreviation	Description
Insight from Research - Content Knowledge	IR-CK	The teacher describes something that they learned, content they were exposed to, or a unique activity that they participated in as an undergraduate during the URE
Insight from Research - Confidence Growth	IR-CG	Teacher describes how their UREs have boosted their confidence in their STEM Content Knowledge, as a STEM Role Model, or as a STEM teacher
Insight from Research - Positive Outcomes	IR-POS	Positive outcomes that result when a teacher shares aspects of their UREs with others.
Insight from Research - Negative Outcomes	IR-NEG	Negative outcomes that result when a teacher shares aspects of their UREs with others.
Insight from Research - Teaching Motivation	IR-TM	Teachers share how their research experience may have further motivated them to pursue teaching.
Insight from Research - No Application	IR-NA	Teacher describes why they feel their research experience does not really shape their current teaching
Insight from Research - No Experience	IR-NE	Teacher mentions that they have no recollection of their research experience
Insight from Research - Importance of Literature	IR-IL	The teacher realizes during their research experience about the importance of keeping up and assessing literature and background context on their topic of interest. They may also describe how they carry this significance into their teaching
Insight from Research - Research Protocol	IR-RP	Teachers realize during their research experience about how research is an iterative and methodical process. They may describe how they learned how to engage with a scientific investigation or learned about different aspects of the nature of research.
Insight from	IR-ASRI	The teacher describes how their research experience made them more aware of how social

Research - Awareness of Social/Racial Issues		and racial issues should be discussed or how practices in support or social and racial equity should be used in their classes, importance of understanding diversity for building relationships with students, or inclusion.
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STEM Subjects Taught by Teachers

Figure A1.1: Breakdown of STEM Subjects Taught by Teachers who were Interviewed in Chapter 1. Grade levels are combined in this figure due to the small size of middle school instructors featured in the study. Advanced placement courses are also grouped together due to the sample size being too small for a separate figure.



BURET-TAMUS Item List (For Students with UREs)

Figure A2.1: The following is the complete item list and prompts for the BURET-TAMUS Instrument

URE Structure

For this survey, a research experience is defined as lab work that you have done or contributed for a summer research program, for a research-focused internship at another institution, for research credit, or for a multi-week project in a lab course.

Please answer the following questions by selecting the response that most closely describes your research experience or by describing what you have experienced.

Q.1: Have you had or are currently in a research experience? Select all that apply.

- a. I have done a summer research program
- b. I have done or I am in a research-focused internship
- c. I have done or I am doing a multi-week research project for a course
- d. I have done or I am doing research as a volunteer
- e. I have done or I am doing research for credit

Q.2: Briefly, could you explain the research project you worked on most recently?

Q.3: Please indicate to what extent you agree or disagree with the following statements.

**Strongly Disagree (1), Somewhat Disagree (2), Neither Disagree or Agree (3),
Somewhat Agree (4), Strongly Agree (5), N/A (6)**

- 1. In the research experience I had in a course, the course structure supported my engagement in research
- 2. In the research experience I had in a course, the course structure inhibited my engagement in research
- 3. The support I received from my research mentor was affected by the calendar of my summer research program or internship
- 4. My ability to learn skills and scientific information for my research project was affected by the structure and time I had in my research experience

Mentor-Mentee Dynamics

The following questions concern the work dynamic you had with your research mentor.

For this survey, a research mentor is defined as someone you have worked with collaboratively in scientific research who guided you over the course of the research collaboration through their experience, advice, skills, knowledge, and support.

Please answer the following questions by selecting the response that most closely describes your most recent research experience or by describing what you have most recently experienced.

Q.4: The individual who I identify as my primary research mentor is...

- a. A Graduate Student
- b. A Faculty Member
- c. A Lab Scientist
- d. A Postdoctoral Scholar
- e. A Undergraduate Student
- f. Other -

Q.5: In general, how often did you interact with your primary research mentor about the research project?

- a. Everyday

- b. Once a Week
- c. Once a Month
- d. Once a Semester
- e. Other -

Q.6: How long have you been mentored by your primary research mentor (in months)?

Q.7: What is the primary method of communication with your research mentor?

- a. Email
- b. Zoom or Video Calls
- c. Text
- d. In-person meetings
- e. Other -

Q.8: Please indicate to what extent you agree or disagree with the following statements in terms of your experience with your most recent research mentor.

Strongly Disagree (1), Somewhat Disagree (2), Neither Disagree or Agree (3), Somewhat Agree (4), Strongly Agree (5), N/A (6)

1. I felt that I had sufficient meetings with my mentor to feel supported in research
2. My research mentor made me feel seen and included in the research lab
3. I felt comfortable talking with my mentor if I needed help with my research project
4. My research mentor demonstrated to me the life as a scientist
5. I felt that my research mentor was able to help me get closer to achieving my academic and professional goals
6. I felt that expectations between my research mentor and I were clearly laid out and reasonable

Student Exposure to Teaching and Mentoring Practices

The following questions concern how you learned knowledge and skills in research from your research mentor.

Please answer the following questions by selecting the response that most closely describes your most recent research experience or by describing what you have most recently experienced.

Q.9: Please describe what actions your research mentor took to teach you scientific knowledge (e.g. facts, theories, principles) for your research project.

Q.10: Please describe what actions your research mentor took to teach protocols and techniques for your research project.

Q.11: Please describe what actions your research mentor took to teach you data analysis for your research project.

Q.12: How did you learn to address limitations of your experimental design in research? Select all that apply.

- a. I learned to address the limitations of my experiment by making connections to other experiments in the literature
- b. I simply described the limitations that I experienced in my research project
- c. I had conversations with my research mentor about the experiment and its limitations
- d. Other -

The following questions concern how your research mentor supported you.

Answer the following questions by selecting the response that most closely describes your most recent research experience or by describing what you have most recently experienced.

Q.13: Please describe what actions your research mentor took to help you to communicate (poster presentations, oral presentations, lab reports, research group meetings, etc.) your research findings.

Q.14: Please describe what actions your research mentor took to guide/support you at the beginning of the research project.

Q.15: Please describe what actions your research mentor took to set expectations for the research project.

Q.16: Please describe how your research mentor provided you feedback on your research work.

Q.17: How did your research mentor foster your independence during the research project, if at all?

Q.18: Please indicate to what extent you agree or disagree with the following statements.

Strongly Disagree (1), Somewhat Disagree (2), Neither Disagree or Agree (3), Somewhat Agree (4), Strongly Agree (5), N/A (6)

- 1. At the end of my research experience, I felt comfortable interpreting my results
- 2. At the end of my research experience, I felt comfortable making conclusions of my work
- 3. At the end of my research experience, I felt comfortable justifying my experimental design and methods
- 4. At the end of my research experience, I felt comfortable connecting my results to the research purpose/motivation
- 5. At the end of my research experience, I felt comfortable proposing the next steps of my project

Research Motivations

The following questions concern your motivations for pursuing undergraduate research.

Please answer the following questions by selecting the response that most closely describes your research experience or by describing what you have experienced.

Q.19. Why did you initially look for a research experience? Select all that apply.

- a. Because I was told I would need research experience for my career
- b. To meet a requirement (Academic, Financial, etc.)
- c. Out of curiosity on the topic
- d. Because this specific project was interesting to me
- e. To work with a specific person on the team
- f. Other -

Q.20: What were your primary goals when you first started your research experience? Select all that apply.

- a. To learn relevant techniques
- b. To meet a requirement (Academic, Financial, etc.)
- c. To learn more about the topic
- d. To boost my resume (Letter of Rec)
- e. Other -

Q.21: Now that you have/had your research experience, has it fulfilled your initial motivation for research or changed it?

- a. Yes, it has fulfilled my initial motivations in some/all ways (please explain)
- b. No, it has not fulfilled my initial motivations in some/all ways (please explain)
- c. It has changed my initial motivations (please explain). For example, I have changed career paths in light of this research

Student STEM Identity

The following questions concern your identity and personal background and how it affected your research experience(s).

Please answer the following questions by selecting the response that most closely describes your most recent research experience or by describing what you have most recently experienced.

Q.22: To what extent did your research mentor introduce you to diverse role models in your field of study?

- a. Not at all
- b. To a small extent
- c. To a great extent

Q.23: Please describe any ways in which your mentor(s) challenged any stereotypes that you had about research or researchers.

Q.24: How did your research mentor make you feel included in the lab, if at all?

Q.25: How often does your mentor share stories of their personal adversities and obstacles they faced due to their background?

- a. Frequently
- b. Not often
- c. Only once or twice
- d. Never

Q.26: Have you ever felt like your identity affected how your mentor viewed you?

- A. Frequently
- B. Not often
- C. Only once or twice
- D. Never

Student Past and Lived Experiences

The following questions concern your personal experiences and skills that you obtained from your research experience.

Please answer the following questions by selecting the response that most closely describes your most recent research experience or by describing what you have most recently experienced.

Q.27: In what ways, if any, has your mentor connected with you beyond formal professional settings to understand your background, experiences, or skills? Please provide examples in the space below.

Q.28: How have you drawn upon your personal experiences, cultural background, or skills learned outside of school to enhance your research experience? What aspects of your background do you feel have been particularly valuable?

For example, a student whose family owns a farm might apply their knowledge of crop cycles or irrigation systems to an environmental science project. Or someone who grew up in a bilingual household might use their language skills to conduct interviews or translate research materials.

Q.29: How often do you draw on your skills, experiences, or insights from your cultural/community background during your research experience? This could include using your background to inform your research interests, to shape your approach to problems, or to provide unique perspectives in your work.

- a. Never
- b. Rarely
- c. Sometimes
- d. Often

- e. Very Often

Q.30: In what ways has your research experience allowed you to build on or apply your skills, experiences, or knowledge gained from your past experiences, cultural background, family, or community? Type [N/A] if not applicable.

Q.31: Have you encountered any challenges in connecting your skills, experiences, or knowledge gained from your cultural background, family, or community with your research work? If so, please explain. Type [N/A] if not applicable.

Q.32: What specific aspects of your skills, experiences, or knowledge gained from your cultural background, family, or community do you wish were more recognized or utilized in your research experience? Type [N/A] if not applicable.

Q.33: How do you think research mentors could make better use of students' different backgrounds and experiences when working on projects together?

STEM Confidence

The following questions concern your belonging and confidence as a science researcher.

Please answer the following questions by selecting the response that most closely describes your most recent research experience or by describing what you have most recently experienced.

Q.34: When receiving feedback from your mentor, how often was your work acknowledged?

- a. Always/Most of the time
- b. Often
- c. Half the time
- d. Not often
- e. Never/Very Rarely

Q.35: Were you ever invited to social events outside of research? (Ex: Hikes, parties, lunches/dinners, potlucks, etc.)

- a. Yes
- b. No
- c. N/A

Q.36: At these events did you feel like you were able to fit in? (Ex: Felt comfortable talking to people, didn't feel like an outsider, etc.)

- a. Included
- b. Mostly Included
- c. Mostly Excluded

- d. Did not attend events
- e. Was not invited to events

Q.37: How did your mentor, if at all, give time for you to learn about their background and story?

Q.38: What steps did your research mentor take to be respectful of your identity (culture, pronouns, name pronunciation) if applicable?

Q.39: After participating in research, do you feel more confident in being a scientist? If so, why?

Integration into Academia

The following questions concern research and your integration into the STEM community.

Please answer the following questions by selecting the response that most closely describes your research experience or by describing what you have experienced.

Q.40: In research, have you been offered opportunities to network in a professional setting outside of the lab?

- a. Yes, by my mentor
- b. Yes, by my research mentor
- c. No
- d. Other -

Q.41: If so, what were some opportunities you were provided with?

- a. Seminars
- b. Guest Lectures
- c. Workshops
- d. Poster Sessions
- e. Conferences
- f. Panels
- g. Fairs
- h. Other -

Q.42: If you were provided with these opportunities, how many have you participated in?

- a. All of them
- b. Most of them
- c. Some of them
- d. None of them
- e. N/A

Q.43: If you were provided the opportunities and did not attend, what were some reason(s) you did not attend?

- a. I had schedule/timing conflicts
- b. I was too busy to attend
- c. The location made it too difficult for me to attend
- d. I was not interested in the particular event (elaborate below)
- e. I did not feel like that particular event would be valuable (elaborate below)
- f. I was informed about the event last minute
- g. I did not feel comfortable attending the event
- h. Other -
- i. I attended!

Q.44: If you had at least one of these opportunities (i.e. see Q.41), rate your level of agreement with the following statements.

Strongly Disagree (1), Somewhat Disagree (2), Neither Disagree or Agree (3), Somewhat Agree (4), Strongly Agree (5), N/A (6)

- 1. The opportunity connected me with peers, scientists, and/or researchers with whom I discuss scientific ideas.
- 2. The opportunity provided me with resources to further my scientific career.
- 3. The opportunity has shown me how my project connect to the broader scientific community
- 4. The opportunity left me feeling more confident in my scientific identity.

Demographic Questions

DQ 1 What is your name?

DQ 2 What is your UC Berkeley student email address?

DQ 3 What is your major/minor?

DQ 4 Are you a first generation college student?

- a. No
- b. Yes

DQ 5 Are you a transfer student?

- a. Yes
- b. No
- c. Other

DQ 6 Which ethnicity do you primarily identify with? If you are comfortable, use the text box to provide us with more scientific information?

- a. American Indigenous or Native American
- b. Asian/Asian-American
- c. Black or African-American
- d. Hispanic or Latinx

- e. White or Caucasian
- f. Mixed
- g. Pacific Islander or Native Hawaiian
- h. Other -

DQ 7 Which of the following best describes your gender identity?

- a. Cis-male
- b. Cis-female
- c. Trans-man
- d. Trans-female
- e. Non-binary/third gender
- f. Prefer not to say
- g. Other -

DQ 8 Are you an International Student?

- a. Yes
- b. No

DQ 9 Is English your first language?

- a. Yes
- b. No

DQ 10 What is the highest level of education obtained by either of your parents?

- a. Less than High School
- b. High School
- c. Associate's Degree (ex: AA, AS, etc)
- d. Vocational Training or Certificate
- e. Bachelor's Degree (ex: BA, BS, etc)
- f. Master's Degree (ex: MA, MS, etc)
- g. Professional Degree (ex: MD, DDS, PhD, JD, etc)

DQ 11 What year are you in your academic track?

- a. 1st Year
- b. 2nd Year
- c. 3rd Year (or 1st Year Transfer)
- d. 4th Year (or 2nd Year Transfer)
- e. 5th Year and up

DQ 12 Are you a student with DSP accommodations?

- a. Yes
- b. No
- c. I am currently in the process of getting an accommodation
- d. Prefer not to say

DQ 13 Did you receive any of the following to help with expenses & funding for college? Select all that apply.

1. Scholarships
2. Financial Aid or Grants
3. Loans
4. Other
5. None

DQ 14 Do you have any other comments on your research experience or any feedback on this survey?

Alternate Survey Item List (For Students without UREs)

Figure A2.2: The following is the complete item list and prompts for the Alternate Survey Instrument

Course Structure

Please answer the following questions by selecting the response that most closely describes your experience or by describing what you have experienced.

Q.1: Which types of science courses have you taken so far at UC Berkeley?

Q.2: Please indicate to what extent you agree or disagree with the following statements.

Strongly Disagree (1), Somewhat Disagree (2), Neither Disagree or Agree (3), Somewhat Agree (4), Strongly Agree (5), N/A (6)

1. In general, course structure helped my engagement in my studies
2. In general, course structure inhibited my engagement in my studies
3. The support I received from my research mentor was affected by the academic calendar
4. My ability to learn skills and scientific information for my major was affected by the course structure and time I had in lecture

Teaching Practices in STEM

The following questions concern how you learned knowledge and skills from your most recent lab course, if applicable.

Please answer the following questions by selecting the response that most closely describes your most recent experience or describe what you have experienced.

Q.3: Please describe what actions your instructor in your most recent lab course took to teach you scientific knowledge (e.g. facts, theories, principles) for the class, if applicable.

Q.4: Please describe what actions your instructor took to teach about techniques, protocols, or instruments related to your most recent lab course, if applicable.

Q.5: Please describe what actions your instructor took to teach you data analysis related to your most recent lab course, if applicable.

STEM Identity

The following questions concern your identity and personal background and how it affected your experience(s) in your major.

Please answer the following questions by selecting the response that most closely describes your most recent experience or describe what you experienced.

Q.6: To what extent have your instructors introduced you to diverse role models in your field of study?

- a. Not at all
- b. To a small extent
- c. To a great extent

Q.7: Please describe any ways in which your instructors challenged any stereotypes that you had about research or scientists.

Q.8: How did your instructors make you feel included in class, if at all?

Q.9: How often do your instructors share stories of their personal adversities and obstacles they faced due to their background?

- a. Frequently
- b. Not often
- c. Only once or twice
- d. Never

Q.10: Have you ever felt like your identity affected how your instructor viewed you?

- a. Frequently
- b. Not often
- c. Only once or twice
- d. Never

Student Past and Lived Experiences

The following questions concern your personal experiences and skills that you obtained being a student.

Please answer the following questions by selecting the response that most closely describes your most recent experience or by describing what you have most recently experienced.

Q.11: In what ways, if any, has your GSI/instructors connected with you beyond formal professional settings to understand your background, experiences, or skills? Please provide examples in the space below.

Q.12: How have you drawn upon your personal experiences, cultural background, or skills learned outside of school to enhance your major courses? What aspects of your background do you feel have been particularly valuable?

For example, a student whose family owns a farm might apply their knowledge of crop cycles or irrigation systems to an environmental science project. Or someone who grew up in a bilingual household might use their language skills to conduct interviews or translate research materials.

Q.13: How often do you draw on your skills, experiences, or insights from your cultural/community background during your major courses? This could include using your background to inform your research interests, to shape your approach to problems, or to provide unique perspectives in your work.

- a. Never
- b. Rarely
- c. Sometimes
- d. Often
- e. Very Often

Q.14: In what ways have your major courses allowed you to build on or apply your skills, experiences, or knowledge gained from your cultural background, family, or community? Type [N/A] if not applicable.

Q.15: Have you encountered any challenges in connecting your skills, experiences, or knowledge gained from your cultural background, family, or community with your research work? If so, please explain. Type [N/A] if not applicable.

Q.16: What specific aspects of your skills, experiences, or knowledge gained from your cultural background, family, or community do you wish were more recognized or utilized in your research experience? Type [N/A] if not applicable.

Q.17: How do you think science instructors could make better use of students' different backgrounds and experiences when teaching?

Student Confidence

The following questions concern your belonging and confidence as a science student.

Please answer the following questions by selecting the response that most closely describes your most recent experience or by describing what you have most recently experienced.

Q.18: In general, when receiving feedback from your GSI in class, how often was your work acknowledged?

- a. Always/Most of the time
- b. Often
- c. Half the time
- d. Not often
- e. Never/Very Rarely

Q.19: Have you participated in any social events that have been hosted or were related to your major department?

- a. Yes
- b. No
- c. N/A

Q.20: So far in your major program, did you feel like you fit in or belonged? (Ex: Felt comfortable talking to people, didn't feel like an outsider, etc.)

- a. Included
- b. Mostly Included
- c. Mostly Excluded

Q.21: How have your GSIs, if at all, taken the time for you to learn about their background and story?

Q.22: What steps did your GSIs take to be respectful of your identity (culture, pronouns, name pronunciation, etc.) if applicable?

Q.23: Now that you are a student at Cal, do you feel more confident in being a scientist? If so, why?

Integration into Academia

The following questions concern research and your integration into the STEM community.

Please answer the following questions by selecting the response that most closely describes your experience or by describing what you have experienced.

Q.24: Have you been offered opportunities to network in a professional setting outside of class?

- a. Yes, by my instructor
- b. Yes, by my club or student organization

- c. Yes, by my department or my major program
- d. No
- e. Other -

Q.25: If so, what were some opportunities you were provided with?

- a. Seminars
- b. Guest Lectures
- c. Workshops
- d. Poster Sessions
- e. Conferences
- f. Panels
- g. Fairs
- h. Other -

Q.26: If you were provided with these opportunities, how many have you participated in?

- a. All of them
- b. Most of them
- c. Some of them
- d. None of them
- e. N/A

Q.27: If you were provided the opportunities and did not attend, what were some reason(s) you did not attend?

- a. I had schedule/timing conflicts
- b. I was too busy to attend
- c. The location made it too difficult for me to attend
- d. I was not interested in the particular event (elaborate below)
- e. I did not feel like that particular event would be valuable (elaborate below)
- f. I was informed about the event last minute
- g. I did not feel comfortable attending the event
- h. Other -
- i. I attended!

Q.28: If you had at least one of these opportunities (i.e. see Q.25), rate your level of agreement with the following statements.

Strongly Disagree (1), Somewhat Disagree (2), Neither Disagree or Agree (3), Somewhat Agree (4), Strongly Agree (5), N/A (6)

1. The opportunity connected me with peers, scientists, and/or researchers with whom I discuss scientific ideas.
2. The opportunity provided me with resources to further my scientific career.
3. The opportunity has shown me how my project connect to the broader scientific community
4. The opportunity left me feeling more confident in my scientific identity.

Demographic Questions

DQ 1 What is your name?

DQ 2 What is your UC Berkeley student email address?

DQ 3 What is your major/minor?

DQ 4 Are you a first generation college student?

- a. No
- b. Yes

DQ 5 Are you a transfer student?

- a. Yes
- b. No
- c. Other

DQ 6 Which ethnicity do you primarily identify with? If you are comfortable, use the text box to provide us with more scientific information?

- a. American Indigenous or Native American
- b. Asian/Asian-American
- c. Black or African-American
- d. Hispanic or Latinx
- e. White or Caucasian
- f. Mixed
- g. Pacific Islander or Native Hawaiian
- h. Other -

DQ 7 Which of the following best describes your gender identity?

- a. Cis-male
- b. Cis-female
- c. Trans-man
- d. Trans-female
- e. Non-binary/third gender
- f. Prefer not to say
- g. Other -

DQ 8 Are you an International Student?

- a. Yes
- b. No

DQ 9 Is English your first language?

- a. Yes
- b. No

DQ 10 What is the highest level of education obtained by either of your parents?

- a. Less than High School

- b. High School
- c. Associate's Degree (ex: AA, AS, etc)
- d. Vocational Training or Certificate
- e. Bachelor's Degree (ex: BA, BS, etc)
- f. Master's Degree (ex: MA, MS, etc)
- g. Professional Degree (ex: MD, DDs, PhD, JD, etc)

DQ 11 What year are you in your academic track?

- a. 1st Year
- b. 2nd Year
- c. 3rd Year (or 1st Year Transfer)
- d. 4th Year (or 2nd Year Transfer)
- e. 5th Year and up

DQ 12 Are you a student with DSP accommodations?

- a. Yes
- b. No
- c. I am currently in the process of getting an accommodation
- d. Prefer not to say

DQ 13 Did you receive any of the following to help with expenses & funding for college? Select all that apply.

- 1. Scholarships
- 2. Financial Aid or Grants
- 3. Loans
- 4. Other
- 5. None

DQ 14 Do you have any other comments on your research experience or any feedback on this survey?

BURET-TAMUS Exit Interview Protocol

Figure A2.3: Exit Interview Protocol for BURET-TAMUS Respondents who were Interested in Further Study Participation

Ask the questions below! Follow up questions are fine, changing the wording is also fine!

Ask the question even if it is repetitious! Please leave any suggestions below or leave a comment on this document!

BEFORE RECORDING:

Hello, my name is [Interviewer Name]. Thank you for taking the time to meet with me today. Before we begin, I would like to go over some information on our Consent Form.

[Researcher reads the Purpose, Procedure, Risks, Confidentiality, Future Use, Compensation, Rights, and Questions sections of the Consent Form]

In-Person: You have been provided a copy of this consent form. You may take time now to review it or ask me any questions. Otherwise, you may provide your consent by signing the form or decline to participate right now.

If you are on Zoom, then they will have already signed the consent form electronically in the email you sent to them prior to the interview.

Okay, do you have any questions before we get started?

BEGIN RECORDING:

1. Student Research Experience:

- Have you participated in undergraduate research at UC Berkeley?
- If No, skip to QUESTION 2

If Yes, continue below and skip to QUESTION 3 when done

- What kind of research experience was it?
- How long have you been participating in undergraduate research?
- Why did you start to participate in undergraduate research?
- What is your current or main research project about?
- What does a typical research day look like in your case?
- Is your research mentor a graduate student, faculty member, or some other type of researcher?
- How did they help you in research when you first started working with them?
- How has their support changed since then, if at all?
- What does your mentor typically do when they are teaching you scientific knowledge in the lab?
- What about lab protocols/techniques?
- What about data analysis?
- How did your mentor help you communicate your research findings?
- How did your mentor set expectations in the research project?
- How did your mentor provide you feedback on your work?
- How did your mentor foster your independence during the research project?
- What else, if anything, do you think they should do to help you learn things in research?
- How is your research experience structured and how do you think it affects your learning of scientific skills/concepts/analysis?
- How did your research mentor make you feel included in the research lab if at all?
- How have you drawn upon your personal experiences, cultural background, or skills learned outside of school to enhance your research experience? What aspects of your background do you feel have been particularly valuable?
- How do you think research mentors could make better use of students' different backgrounds and experiences when working on projects together?
- After participating in research, do you feel more confident about being a scientist?
- Is there anything else about your research experiences that you would like to share with us?

2. Only if they answered no to Question 1!

- Do you have an interest in participating in research?
- [If so] Have you experienced any difficulties in getting a research experience?
- [If no] Why not?
- Have you been mentored by someone in other aspects of your life so far?
- [If so] Can you share what you felt worked for you in terms of mentoring in that experience?
- Can you describe what actions your instructor in your most recent lab course took to teach you scientific content knowledge (e.g. facts, theories, principles, etc.)?
- What actions did they take for lab protocols and techniques?
- What about data analysis?
- How did your STEM instructors challenge any stereotypes you had about research or scientists?
- How did your STEM instructors make you feel included in class if at all?
- How have you drawn upon your personal experiences, cultural backgrounds, or skills learned outside of school to enhance your experiences in your major courses? What aspects of your background do you feel have been particularly valuable?
- How do you think science instructors could make better use of students' different backgrounds and experiences when teaching?
- As a student at Cal, do you feel more confident in being a scientist? Why or why not?

3. Conceptions of Mentoring and Teaching:

- What does effective mentoring look like to you in undergraduate research or in class?
- What does effective teaching look like to you in undergraduate research or in class?
- Has your view changed since you have started research or for any other reason?
- If yes to Question 1: What role did you expect for your research mentor when you first started research?
- If Yes, to Question 1: What about your role?

4. Survey Feedback

- Provide Students with Item List and give them time to look over it if they would like.
- Do you recall your impressions of the BURET Teaching and Mentoring Survey that you completed this semester in CHEM 135?
- Were there any particular questions that stood out to you and why?
- Are there any other aspects of the research experience that you feel we should ask students?
- How do you feel about the format of the survey?
- Did you feel that you could accurately represent your research experience through the survey questions and answer choices?
- If yes to Question 1: Read the following selected survey questions to repeat to students...
- In your most recent research experience, do you feel you had sufficient meetings with your mentor?
- In your most recent research experience, do you feel that you learned more about the life of a scientist?

- In your most recent research experience, do you feel that your research mentor helped you get closer to your academic and professional goals?
 - In your most recent research experience, do you feel comfortable interpreting your results?
 - In your most recent research experience, do you feel comfortable making conclusions about your work?
 - In your most recent research experience, do you feel comfortable justifying your experimental design?
 - In your most recent research experience, do you feel comfortable connecting my results to the research purpose/motivation?
 - In your most recent research experience, do you feel comfortable proposing the next steps of my project?
- Do you have other comments or feedback that we can use to improve the Survey?
-

Survey Demographics (BURET-TAMUS)

Table A2.1: Participant Ethnicities

Which ethnicity do you identify with?	
American Indigenous or Native	1 (1.33%)
Asian/Asian-American	47 (62.6%)
Black or African American	0 (0%)
Hispanic or Latinx	5 (6.66%)
White or Caucasian	18 (24.0%)
Mixed Race	2 (2.66%)
Pacific Islander or Native Hawaiian	0 (0%)
Other	2 (2.66%)

Table A2.2: Participant Majors

What is your major?	
Data Science	1 (1.33%)
Applied Math	1 (1.33%)
Chemistry	16 (21.3%)
Chemistry Biology	37 (49.3%)
Molecular and Cell Biology	4 (5.3%)
Molecular Environmental Biology	4 (5.3%)
Microbiology	1 (1.33%)

Chemical Engineering	4 (5.3%)
Cognitive Science	1 (1.33%)
Bioengineering	4 (5.3%)
Integrative Biology	1 (1.33%)
Biotechnology	1(1.33%)
Electrical Engineering and Computer Sciences	1(1.33%)

Table A2.3: Highest Level of Participant's Parent's Education

Highest Level of Education of Your Parents?	
Less than High School	1 (1.33%)
High School	13 (17.3%)
Associate's Degree (ex: AA,AS,etc.)	5 (6.66%)
Bachelor's Degree (ex: BA, BS, etc.)	11 (14.6%)
Vocational Training or Certificate	1 (2.63%)
Master's Degree (ex: MA, MS, etc.)	27 (36%)
Professional Degree (ex: MD, DDs, Ph.D., etc.)	18 (24.0%)

Table A2.4: Participant Disability Accommodations

Are you a student with DSP Accommodations?	
Yes	9 (12.0%)
No	62 (82.7%)
In the process of accomodation	1 (2.63%)
Prefer not to say	3 (4%)

Table A2.5: First Generation Status

Are you a first generation student?	
Yes	23 (30.6%)
No	52 (69.3%)

Table A2.6: Transfer Student Status

Are you a Transfer Student?	
Yes	12 (16.0%)

No	63 (84.0%)
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Table A2.7: Gender Identity Status

What is your gender identity?	
Male	35 (46.6%)
Female	35 (46.6%)

Table A2.8: International Student Status

Are you an International Student?	
Yes	17 (22.6%)
No	58 (77.3%)

Table A2.9: Academic Year

Academic Track Year?	
Junior	61 (81.3%)
Senior	13 (17.3%)

Table A2.10: Number of UREs that Participants have Engaged in

Number of URE?	
1	30 (46.6%)
2+	35 (53.4%)

Table 14 A2.11: English Speaking Status

Is English your First Language?	
Yes	51 (68%)
No	24 (32%)

BURET-BOBYUR Workshop Series Pre-Survey Form

Figure A3.1: BURET-BOBYUR Workshop Series Pre-Survey Form with Instructions

Welcome to the BURET Workshop Series!

Please fill out this pre-session survey to let the workshop facilitators know more about your mentorship experience.

Question 1: Have you mentored undergraduate researchers previously?

- Yes
- No

Question 2: If so, please list the mentorship experience (e.g., summer undergraduate research program, another undergraduate in your lab, etc.).

Question 3: Have you participated previously in a mentoring workshop or training?

Question 4: If so, please list the workshop or training you participated in.

Question 5: Will you be mentoring one or more undergraduate students this summer in a research project? Will you continue to mentor the student(s) in research after this summer?

Question 6: Whom do you talk to, if anyone, about mentoring your undergraduate and how they are progressing in their development as a researcher?

- Your advisor/PI
- Another grad student in your group
- Another grad student outside your group
- A postdoc in your group
- A classmate
- A friend
- A family member
- N/A
- Other

Question 7: If you selected “other” above, please explain.

Question 8: In preparation for our first session on Friday, June 6th (11:00 am PST), please briefly respond to the following in 1 to 3 sentences:

1. Regarding your role as a mentor, what are your primary goals for this summer?
2. What is your current plan for meeting these goals?

Question 9: In preparation for our first session on Friday, June 6th (11:00 am PST), please briefly respond to the following in 1 to 3 sentences:

1. What are your main expectations for undergraduate researchers?
2. How do you communicate these expectations to your undergraduate researchers?
3. Think about some of the most useful strategies you have developed (or would like to develop) for teaching and mentoring undergraduates. Describe one or two strategies here.

Question 10: In preparation for our first session on Friday, June 6th (11:00 am PST), please list some mentorship strategies for cultivating a sense of belonging that you currently use or may consider using. If you do not currently use any strategies to

improve sense of belonging in your mentorship, please write a question you have about this aspect of mentorship.

Question 11: In preparation for our first session on Friday, June 6th (11:00 am PST), how do you envision supporting your mentee in order to develop your relationship with your mentee throughout the research project?

Question 12: Do you have any food allergies or dietary restrictions? Please also specify if the severity of your allergy requires the food item to be absent from everyone else's meal as well.

Video Recording Guidelines

Figure A3.2: Video Recording Guidelines for Participating Mentors in Chapter 3's Study with Instructions

Greetings!

We're excited to have you and your mentee participate in our study on student learning in undergraduate research experiences!

The first component of the study involves you providing a video recording to us about a research teaching or mentoring interaction that you will have with your mentee that you would like feedback on and or would like to improve on. Some examples could include:

- Providing constructive feedback to your mentee on the materials they have produced for the research project such as experimental results/data analyses, elevator pitches, poster presentations, etc.
- Implementation of a teaching plan or strategy, e.g. to instruct on an experimental technique, instrument, or protocol
- Asking your mentee open-ended questions or using other knowledge checks to assess their learning in the research project

The video recording should be about 10-15 minutes long. You may record a longer interaction if needed, but we will ask for you to identify a 10-15 minute focal clip for feedback. You may record via phones, video cameras, or online recording software. Make sure that the audio in the recording is clear and at appropriate volumes. If possible, record your video on something such as Zoom that can produce a basic audio transcript. Only the research team will have access to the video recording and any private information disclosed in the video will be de-identified in audio transcriptions used by the research team.

We'd be happy to help if you have any questions or if you need any assistance with obtaining and sending the video recording.

- BURET Research Team

Dr. Anne Baranger (abaranger@berkeley.edu)
Dr. Elisa Stone (emstone@berkeley.edu)
Anthony Garcia (agarcia464@berkeley.edu)

Written Reflection Prompt

Figure A3.3: Written Reflection Prompt for Participating Mentors in Chapter 3's Study with Instructions

The second component of the research study involves providing to the research team a written reflection on your video recording. The written reflection should be included in your video recording submission or at least within a few days after the video was recorded. Your written reflection should be about 1-2 pages (single-spaced) in length and should address the following questions:

- Why did you choose this lesson/topic/interaction for your video?
- Did you have a specific goal in mind? Please give some context for your video.
- What aspects of this video recording would you like us to provide feedback on?
- What do you think went well with regards to supporting development of your mentee's understanding of the research project?
- What would you like to do differently next time?

After the research team has had time to analyze the video and written reflection, we will invite you to the next component of the research study which is a feedback session later in the summer on these materials. We may also interview you and/or your mentee at a later point this summer or next fall. More information will be provided on this in the future. If you and/or your mentee have time conflicts or limited availability in the future, please let us know.

We'd be happy to help if you have any questions or if you need any assistance with any aspect of the written reflection.

- BURET Research Team
Dr. Anne Baranger (abaranger@berkeley.edu)
Dr. Elisa Stone (emstone@berkeley.edu)
Anthony Garcia (agarcia464@berkeley.edu)

Workshop Mentors Interview Protocol

Figure A3.4: Final Interview Protocols for Participating Mentors in Chapter 3's Study that were Completed after Second Coaching Sessions

Interview Protocol for Mentors

BURET Workshop Context:

1. Why did you want to get involved in the BURET Workshop series?
2. What concepts or practices from the BURET Workshop Series were most useful or interesting to you in terms of your teaching and mentoring of your research mentee? (I will provide a list of Workshop Topics and Activities!)
3. How was your mentor/mentee dynamic affected by participation in the BURET Workshop Series?

Experiences with Particular Student-Mentee Learning:

4. Did your mentee work on other research projects (lab or course based) before working with you this summer?
5. In what ways have you seen your mentee develop as an independent researcher while working on the research project?
6. In what ways have you seen development in your mentee's proficiency of relevant content knowledge and lab techniques for the research project?
7. Is there anything in particular that you would attribute that development to?
8. How well did you feel your undergraduate connected analysis and interpretation of their data to constructing explanations or models that are relevant to their projects' research question?

Science and Engineering Practices:

9. How would you define mentoring in research (briefly)?
10. How would you define teaching in research (briefly)?
11. Which one of two of these science and engineering practices (I will show them a list) did you try to emphasize the most with your mentee? (Just choose one or two practices that you emphasized)
12. Do you feel that there is a meaningful distinction between your mentoring and teaching practices in research?

Reflecting on the Coaching Videos:

13. From our feedback sessions, was there anything new or different that you did with your mentee?
14. What was your experience in talking with me about your interactions with your mentee? How did it go for you?
15. From our feedback sessions, was there anything that you would have liked more help with?
16. In what ways were recording discussions with your undergraduate mentee useful?
17. How did you grow as a teacher and a mentor as a result of this video analysis and feedback (if at all)?

Background Info (if time permits otherwise skip to the next section):

18. Can you share a little bit about your academic/professional background, and current research area?

19. What are your current career goals?
20. How did you get involved in mentoring undergraduate students?
21. What are your overall goals for the undergraduate researchers that you work with?
22. What do you think are the main responsibilities of a research mentor?

Closing Remarks:

23. In what ways could your research group, department, or institution support you in being a successful mentor to undergraduate researchers?
24. Has mentoring and teaching students affected how you view/think about scientific research?
25. In what ways have you benefited from collaborating with undergraduate researchers during your graduate studies?

Workshop Mentees Interview Protocol

Figure A3.5: Final Interview Protocols for Participating Mentees in Chapter 3's Study that were Completed after Second Coaching Sessions

Interview for Mentees

1. Can you share a little bit about your academic background and your academic/research interests?
2. How did you get involved in undergraduate research at UC Berkeley?
3. Can you describe the research project that you are/were doing at UC Berkeley?
4. What were your goals for the research experience?
5. What were the most critical ideas, skills, or results that you took away from your undergraduate research experience at Cal?
6. How did participating in research change your impression being a graduate student or STEM researcher?
7. What were your impressions of what research would be like before the summer?
8. How did your mentor contribute to your expectations of research and being a researcher?
9. How would you describe the research dynamic between you and your mentor over the summer?
10. Did that dynamic change over time and in what ways?
11. In general, how did your mentor teach you new concepts, techniques, or protocols for the project?
12. Did you learn how to develop or design your own experiments?
13. Did you learn how to make conclusions from your data?
14. How did your mentor acknowledge your personal background or identity if applicable?
15. In what ways or areas, do you wish you received more support from your mentor?

16. Reflecting back, What do you feel are your strengths in your research project?
 17. Reflecting back, What do you feel are your struggles in your research project?
 18. (Ask a question specific to what their mentor has indicated they tried out after the feedback sessions.) For example, your mentor indicated that they started doing X and Y, did you feel that was helpful to you?
 19. How did research change your view of being a scientist or being involved in academia?
 20. Is there anything else you would like to share?
-

BURET-CoTaM Instrument

Objective: We are using the BURET-CoTaM Instrument to identify what specific things graduate student mentors are doing to help their students in the video recordings, coaching sessions, and the written reflections that we have. We added an extra category that is related to specific changes they made from the coaching sessions.

Table A3.1: BURET-CoTam Categories, Codes, and Descriptions

Category	Code	Description
Teaching	Fundamental Research Knowledge	The video contains teaching of research goals, plans, expectations and ideas about the research project. Scenarios include conversations relating to fundamental research knowledge or a review of scientific literature. This code does not include activities that have already happened.
Teaching	Research Procedures	The video contains teaching of research protocols, instruments, skills, or experimental steps for the research project. Scenarios include demonstrations of scientific instruments/skills or a review of experimental design with steps. This code does not include activities that have already happened.
Teaching	Data Analysis and Interpretation	The video contains teaching related to data collection, analysis, and/or interpretation for the research project. Scenarios can include using practices that engage students with science as a body of knowledge such as comparing and contrasting data, discussing experimental data, interpreting data to find meaning, validate theories/hypotheses, evaluate other published work, identify areas where the experiment can be revised, or to inform next steps for the research project. This code does not include activities that have

		already happened.
Teaching	Scientific Communication	The video contains teaching of proper or appropriate scientific communication for the mentee's research project. Examples include practicing for lab group meetings, creating a research poster presentation, creating arguments using scientific rationale and data, creating visual figures, or writing for a publication. This code does not include activities that have already happened.
Teaching	Mentor-Mentee Engagement (Assessment, Active Learning, Mutual Communication)	Mentee is engaged during any instruction provided by the mentor in the research project. They are given an opportunity by the mentor to ask clarifying questions, share input on what to do, and provide feedback. Student is an "active learner". Mentors facilitate student engagement through assessment of knowledge or by having them get "hands on" with the project. For this code to be used, all of the aforementioned criteria must be satisfied in the event of a teaching moment.
Mentoring	Mentor-Mentee Engagement (Requesting Feedback or Input, communicating expectations, connecting things to Mentee's interest and goals)	For this code to be used, mentors must engage mentees with active and intentional integration of several different mentoring practices or moments. Examples include asking the mentee's feedback or input, communication expectations, and connecting things to the mentee's interest and goals.
Teaching	T-Goal	Mentor communicates to mentee a goal they plan to teach to them in video that is consistent with their written reflection or coaching session.
Mentoring	Establishing the Dynamic	Mentor explains their mentoring goals, approach, expectations, or practices that they would like to use with the mentee in the future. Mentee is able to provide some of their expectations and goals in return.
Mentoring	Research Independence	Mentoring practices related to fostering research independence in the mentee. Examples include giving the mentee more time to themselves to work on

		research, providing space for students to work and learn at their own place, try their own ideas or approach to the project, or keeping track of mentee's goals.
Mentoring	Career Development	Mentoring practices related to academic/career goals, professional development, (physically doing things related to) entering the scientific community. A mentor could support a student by discussing plans for graduate school; supporting their efforts to apply for jobs; preparing them to work independently as a scientist or professional; or enabling them to engage in activities characteristic of scientists (i.e., doing what scientists do).
Mentoring	Psychosocial Support	Mentoring practices related to psychosocial support, community-building, inclusion, getting to know the mentee better. A mentor could support a student by encouraging them to "feel" like a scientist (or other role); feel confident while engaged in research, professional development, presentations, etc.; fostering their sense of belonging, self-efficacy (feeling as though they can do the activities characteristic of scientists). When using this code, mentors are engaged in activities with a goal to impact the way that a student feels (e.g., happiness, satisfaction, confidence, self-efficacy, belonging, curiosity, ownership).
Mentoring	M-Goal	Mentor communicates to mentee a mentoring goal to them in video that is consistent with their written reflection or coaching session
Coaching	Integration of feedback from coaching intervention	Mentor clearly integrates feedback or practices mentioned to them from a coaching session(s) done with the research team.
Coaching	Implementation of stated mentoring approach or goal	Mentor clearly implements a stated teaching or mentoring goal from their written reflections or their coaching session
Coaching	Refinement of previously used mentoring	Mentor uses a mentoring practice that was previously featured in one of their mentoring videos and refines its implementation

	strategy or practice	
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Example of Workshop Exit Ticket, Ticket Responses, and Post-Evaluations (2025)

Figure A3.6: Example of Workshop Exit Ticket, Ticket Responses, and Post-Evaluations that BURET-BOBYUR Workshop Series Participants Completed in Final Session

Question 1: Name one or two things you learned today:

- Students should gain a sense of ownership and independence in their project (x2)
- How to assess students' understanding of the project and its limitations based on poster presentation using questions (x8)
 - [REDACTED]'s comment mentioning: "we always evaluate what undergraduate writes/says rather than their knowledge" was memorable (x3)
- Rubrics and specific requirements for good poster presentation (x5)
- Need to adjust/recalibrate expectations based on mentee's needs (x2)
- How to address undergrad that is not meeting the expectations
- Evidences in evaluating novice to expert progression (x2)

Question 2: What is one thing that could have been improved:

- Have two rubrics on the separate sheets so that it is easier to read through the transcript
- See more explanation of the rubric before using it. It was difficult to evaluate and score discussion for the other excerpt that I did not read.
- Would have like to see actual posters (x2)
- The examples we graded were a little short
- What workshop organizers thought on the excerpts and presentations (x2)
- More time could be provided (x3)
- The first part of activity 1 was a bit long and wasn't really connected/useful fo the next part. Longer time devoted to rating answers may be more helpful.
- The recalibration part could have mimicked the original questions better and have a part reflecting on if the workshop met the expectations of participants
- None :) (x5)

Question 3: Do you have any further suggestions on what to include in the Workshop Series?

- More discussions on cultivating project ownership
- Could cover to mentor multiple mentors in once and how to balance that
- How to engage with quiet undergraduates. Found it difficult to assess and evaluate their progress.

- How to come up with projects that are suited for undergrads and for short-time.

Thinking back over the entire workshop series:

Question 4: New teaching strategies you have used?

- Used appropriate questions to assess students understanding in the beginning and set student's goal and plan for the future (x4)
- How I can help mentee generate a productive poster presentations
- Positive framing / Asset framing (x2)
- CREATE method (x8)
- Elevator pitch: helped me understand my mentee's vision and assess their project understanding/ownership (x6)
- Using rubrics - easier communication, provides good starting point (x2)
- Giving mentees more ownership of the project (e.g. ask them to think next steps)
- Using more structured activities when introducing new topic
- Built-in more times to discuss progression as a researcher and career goals etc
- Do not have a mentee yet, but looking forward to implement these strategies (x6)

Question 5: What did your undergraduate student learn?

- That their mentor genuinely cares about their growth and research goals
- CREATE method helped them how to navigate scientific writing (x5)
- Mentees gained much more confidence (x3)
- My mentee loved the elevator pitch activity and liked that they got feedback from their mentor. (x3)
- Improved presentation in lab meeting and conversations
- Importance of proper communication in science (x2)
- Do not have a mentee yet (x6)

Question 6: How have you changed related to DEIB practices?

- More purposeful in including mentee in lab events (x4)
- I became more confident as well as purposeful in reflecting my practice (x3)
- Became more conscious in actively engaging with other mentees in the labs as well. (x4)
- Considering diverse ideas and making sure all voices are heard
- The idea of "hidden-curriculum"
- Not much was changed – I feel like it wasn't highlighted or mentioned much in the workshop. (x4)
- It is hard to answer — I don't think there is a single strategy.

Question 7: DEIB-related content suggestions?

- The workshop needs more explicit discussion on DEIB topics. The workshop didn't directly address this (x3)
- Suggestions on ways to actually bring in students even before joining the lab
- Possible case studies
- Some consequences of not including DEIB-oriented practices in research

Question 8: Who did you talk to about inclusive mentorship?

- None (x3)
 - Friend (x2)
 - Postdoc in the group (x2)
 - Other labmates (x5)
 - PI
 - I've discussed with generally with everyone
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