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Digging Deeper with Data: Engineering Research Experiences for STEM Undergraduates and Teachers

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Digging Deeper with Data: Engineering Research Experiences for STEM Undergraduates and Teachers

Abstract:

It has become increasingly important for K-12 students to learn how to investigate patterns, correlations, and significance in data. The Berkeley Engineering Research Experiences for Teachers plus Data (BERET+D) pairs undergraduate pre-service teachers and experienced in-service science and mathematics teachers (PSTs and ISTs) to engage in engineering and data science research, exploring and analyzing data sets drawn from a variety of STEM fields and laboratories across the UC Berkeley campus. In addition to conducting independent summer research projects with guidance from university research faculty, the program provides opportunities for: (1) PSTs to develop data science-based lessons inspired by their research and aligned to the Next Generation Science Standards (NGSS), (2) ISTs to create data science-based curricula designed to inspire middle and high school students to see STEM classes as exciting and with real-life applications, and (3) ISTs to collaborate with and mentor PSTs preparing to enter K-12 STEM classrooms. Contributing towards broader impacts, CalTeach recruits a racially and socioeconomically diverse population of PSTs, and all ISTs were recruited from local public schools, in order to educate, prepare, and encourage more minority and female K-12 students to consider higher education and careers in STEM.

During the first two summers of this project (2020-2021), participants completed over forty data-science related projects, developed over thirty K-12 data-science related lesson plans in math, science, and engineering, and created six classroom-ready and publicly accessible (teachengineering.org) curricular units showcasing data science. As an example of these curricular units, and as further evidence of the project's broader impact, one IST has developed an ongoing partnership between their classroom and a research laboratory on campus allowing high school physics students to learn data science techniques by analyzing and interpreting distant satellite signals collected by radio telescopes. Preliminary evaluation of this ongoing project revealed that participants viewed data science as important and essential in K-12 curriculum, that data analysis is a critical and useful skill for youth, and that data science aligns closely with the science and engineering practices called forth by NGSS. Though constrained by work-from-home restrictions due to COVID during the first two years, participants described

their experience as positive and valuable, particularly in conceiving of ways to engage young learners with data-science through remote instruction.

Introduction

Data arising from experiments, observations, and simulations in the natural sciences and engineering, as well as in industrial applications, the social sciences, and other domains, have created enormous opportunities for understanding the world we live in. The pursuit of such understanding requires the development of systems and techniques for processing and analyzing data, which has led to a variety of new fields and professions that collectively make up the growing discipline of "data science." Data science as a topic of study has exploded over the past decade, particularly in higher education, and increasingly at the secondary level as well. Its interdisciplinary nature cuts across STEM fields, while also focusing on solving problems relevant to current challenges we face as a society, making it a particularly appealing topic and skill set to bring to K-12 students.

In order to involve teachers firsthand in scientific research experience in an authentic setting, such a in university laboratories or industry research, multiple organizations have designed and implemented Research Experiences for Teachers (RET) programs with the long-term goal of enhancing STEM learning experiences for K–12 students. In RET programs, teacher participants are guided to engage in research with experienced researchers in a Community of Practice (e.g., faculty, postdoctoral researchers, and graduate students in a laboratory setting). Outcomes of these experiences include increased STEM knowledge and experience, scientific research practices, career awareness, and STEM self-efficacy and identity. RET programs typically aim to support translation of research into classroom practices through curricular development by a Professional Learning Community, which leads to improvements in STEM teaching and learning, and includes outcomes such as increased persistence in STEM teaching and pedagogical content knowledge (Krim et al., 2019).

The Berkeley Engineering Research Experiences for Teachers plus Data Science (BERET+D) is an example of one such RET program. BERET+D pairs pre-service and in-service science and mathematics teachers (PSTs and ISTs) to engage in data science research to investigate patterns, correlations, and significance in data sets drawn from a variety of STEM fields and laboratories across the UC Berkeley campus. Each group of teachers takes what they have learned from their summer research projects to develop grade-appropriate, K-12 standards-based curricular materials which they will teach in their secondary math and science classrooms in the following year. Professional development activities guide teacher participants to develop pedagogical content knowledge to engage their own K–12 students in authentic investigations in the data sciences, and inspire their students to see STEM fields as exciting careers with real-life applications.

The BERET+D program contributes to expanding the diversity of students in engineering, data science and computing fields by recruiting math and science teachers from low-income and underrepresented backgrounds, and ISTs from urban K-12 public schools, who educate, prepare and encourage K-12 students to consider higher education and careers in STEM. Data science has recently become especially cogent for K-12 teachers, as it brings together several STEM fields spanning math, science, engineering and computer science. These interdisciplinary connections align with the currently more integrated nature of STEM in cutting-edge research and higher education, helping to address the isolation of K-12 teachers whose fields have tended to exist in 'math versus science' silos for decades.

Our program evaluation and research for BERET+D focuses on how participation in the program helps PSTs and ISTs develop their understanding of (1) data science, (2) the STEM research process, and (3) how to incorporate data science into K-12 math and science curricula. We also began to investigate how BERET+D participants' engagement in authentic data science research and scaffolded reflections on their experiences allow them to develop expertise in facilitating the development of data science and computational practices for their K–12 students. Here, we report on key components of BERET+D program design and preliminary research findings.

Engaging in Engineering & Data Science Research

In what research projects did teacher participants engage?

During the first two years of the BERET+D program, a total of 36 undergraduate pre-service teachers and 7 in-service teachers engaged in multi-disciplinary engineering research projects with an emphasis on data science across a number of STEM labs and departments at UC Berkeley. Research placements were hosted by faculty and their graduate students in a variety of departments, including Biomechanical Engineering, Civil and Environmental Engineering, Mechanical Engineering, Nuclear Engineering, Astronomy, Cell & Developmental Biology, School of Education, and the Joint Genome Institute. Because these research placements were made during the global Covid-19 pandemic in the summers of 2020 and 2021, the participants primarily engaged in the research remotely.

All teacher participants conducted independent full-time summer research projects with an existing research group on campus in which faculty, postdoctoral researchers, and graduate students were actively involved. The BERET+D program was originally designed so that undergraduate pre-service teachers and experienced in-service teachers were placed in pairs in research laboratories. Veteran teachers benefit from this pairing as they can more quickly adapt to the university environment when they are partnered with undergraduate researchers. The PST undergraduates, in turn, benefit from the experience, perspective, and enthusiasm that veteran teachers bring to the research group, and they enjoy the chance to work with exceptional veteran teachers as role models.

Because of the pandemic, fewer in-service teachers were able to participate in summer research and fewer laboratories were able to take on teacher pairs. However, the 5 teacher pairs that were placed together in laboratories engaged productively and collaboratively in several fascinating research efforts, including a nuclear engineering project examining radon levels at various school sites in the San Francisco Bay Area, a mechanical engineering analyzing drag reduction below the surface of ships, and a bioengineering project exploring extremophiles through metagenomic data analysis. Other pre-service or in-service teachers were placed on their own in a variety of research laboratories, engaged in evaluating agricultural water Consumption in California, studying how health literacy factors associated with individual's health status, investigating the integration of data science and machine learning in educational psychology, quantifying cell stiffness by mechanically modeling microfluids, and other research projects.

Even under the conditions in which all research and meetings were held remotely, participants were exposed to a breadth of other experiences over the summer – from safety and technical training, scientific seminars from nationally renowned scientist, and weekly lab meetings, to professional development workshops on inquiry-based science pedagogy, STEM education, and computing and data science curricular integration – that took full advantage of the strengths of the university.

Outcomes - what did participants learn from engaging in data science- and engineering-focused STEM research?

The BERET+D research team assessed participants' growth in their understanding of data science through comparison of responses to a pre- and post-survey before and after the 8-week program. Participants responded to an open-ended prompt in which they described the skills they expect to use most often as a data scientist. Responses were categorized according to emergent themes. From pre- to post-survey, general skills like persistence were mentioned less frequently, while analytical skills, coding and programming, communication, patience, and curiosity were all considered more important to engaging in data science-related research in post-survey responses.

Additionally, teacher participants were asked to consider the role of bias in data science. Though all respondents disagreed with the assertion that data science is free from bias "because numbers never lie", the open-ended response below is representative of what many articulated:

> *"I agree that numbers are numbers, but the actual process of collecting and interpreting those numbers is a process that is created by the society that we live in. This is like asking whether true objectivity can exist -- it can't in science, in my opinion, because those who perform the experiments, who create the procedures of such experiments, and interpret the results of those experiments, are people whose brains are fundamentally biased by their own life experiences and most readily accessible ideas."*

Moreover, all but one teacher participant shared on post-surveys that their summer experience had changed how they thought about data science in the context of teaching and learning. Representative participant responses include:

"I learned new ways to analyze data, and the importance of reading literature. Also, the importance of validity of data. In addition, how we can truly relate data science and being a researcher to so many different topics in the sciences, and how we can make lesson plans integrating the two! Also, how many interactive resources there are online for students to use!"

"In the process of the research, my research encompassed many aspects such as formulating questions, finding data, doing research to get background information, analyzing data and interpreting results, making models, etc. I hope that this research can reflect in my teaching in the future through me implementing more opportunities to do little research projects in classrooms. I can also talk about what I did in the research as a way to engage students in the process."

"I think my summer experience has given me time to work with analyzing and interpreting data, as well as how to communicate this information. Since I will have a much greater comfort level with these skills, I can incorporate these components in a more accessible way with my students because I can draw from my own challenges from this summer."

Curricular Resources for the K-12 Classroom

What curricular resources did summer research participants develop?

Teacher participants used their summer research experiences as the basis for developing new STEM lessons and classroom curricular materials that specifically highlight aspects of engineering and/or data science. During and after their summer research experience, pre-service and in-service teacher teams worked together to further develop a curricular unit (multiple days to several weeks in length) to be taught in their classrooms during the academic year following their participation in summer research. Graduate student and postdoctoral mentors worked with the teacher teams, allowing the university researchers to gain valuable mentoring and teaching experience by not only helping to guide the teacher teams in laboratory practices but also by participating in developing curriculum for teachers' classrooms during the academic year. By cultivating these communities of practice, we hope to increase the interaction between STEM research and STEM education in a way that attracts middle and high school students to STEM related fields.

BERET+D teacher participants developed a variety of engineering- or data science-based curricular units for use in high school science and math classrooms as part of their summer experience. During the academic year, participating teachers have taught, or will teach their lessons in order to connect contemporary research in STEM to K-12 science and mathematics learning in local schools. The developed curricula are aligned with age-appropriate content and practice standards specified in either the Next Generation Science Standards (NGSS) or the Common Core State Standards for Mathematics (CCSSM). Examples of curricular units developed in BERET+D can be seen in the table below.

STEM research	**Resulting high school STEM lessons**
Nuclear Engineering	● Developing and testing a mobile user interface for detecting radiation levels in the community. ● Analyzing the correlation between air quality and levels of radon in our community, and around the world. ● Understanding radioactivity - isotopes around our school and what can we learn from their presence?
Data Science & Math Education	● Analyzing the environmental and health impacts of industrial combustion near communities of color. ● Developing an argument for health literacy programs based on statistical analysis of environmental impact of local industries on local communities.
Mechanical Engineering	● Using experimental design to analyze data, communicate science ideas, and establish scientific credibility. ● Proposing new structural methods to reduce frictional drag and improve fuel efficiency of maritime shipping vessels.
Metagenomics	● Application of bioinformatics and genomics to understand how E. coli affects our food, our bodies, and leads to food recalls. ● Analyzing the biochemical pathways present in extremophiles to understand how they help sustain and support life in marine ecosystems. ● Analyzing pre-historic genomic samples to identify potential metabolic activity of ancient organisms and to hypothesize the types of environmental conditions during Earth's early existence.

Astronomy	• Developing algorithms to separate signal from noise - how can we develop tests to determine whether a signal is real, is a mistake, or is part of the background noise?

All PSTs were also guided to develop engineering and/or data science-focused lesson plans aligned with their research, which many are currently implementing or intend to implement while student teaching or during their future teaching career. Our experience in using remote modalities over the past two years has proven useful as we look to expand our vision for engaging teachers and students in STEM research, learning, and lesson design for return to classroom settings.

How did research projects translate into STEM learning in the K-12 classroom?

As all instruction and professional development was conducted virtually for the first two years of this project due to COVID-19 restrictions, there were fewer opportunities for BERET+D teacher participants to engage in opportunities to develop and implement their engineering- and/or data science-based curricular units than expected. However, the following case studies highlight the ingenuity and perseverance of our ISTs as they attempted to engage high school students in curricula aligned to their summer research projects through both remote and face-to-face instruction in the classroom.

Case 1 - High School Physics Teacher Mr. L

Mr. L, a physics teacher from the San Francisco Bay Area, was inspired by his participation in BERET+D to plan and implement an on-going series of engineering career panel discussions between university researchers, faculty, and his high school physics students. During the pandemic, Mr. L hosted and facilitated these panels virtually while students were learning remotely. As students returned to in-person instruction during the following year, Mr. L brought several university researchers to his classroom to showcase their research through a series of engineering and astronomy hands-on demonstrations, and to share advice about entering STEM careers. The panel discussion was so well received during the first year that many school faculty and parents attended during the second year. Also as a result, one of Mr. L's colleagues (Ms. N, see below) applied for and participated in the BERET+D program the following year.

Together, Mr. L and Ms. N have collaborated to develop an engineering curricular unit that is closely aligned to the radio astronomy research they both completed while participating in BERET+D. As part of this unit, high school physics students use data collected by Dr. Alex Filippenko's research group at UC Berkeley to use models to demonstrate their understanding of celestial movements including how/why we see phases of the moon, how we can use geometry and algebra to determine distances on Earth's surface, and how we can predict sunrise and sunset times using data science.

Additionally, Mr. L continues to work with UC Berkeley's SETI research team to develop a tutorial (named, "It's a bird, it's a plane, it's, it's… Voyager 1?") for high school students to learn data science techniques to develop algorithms to detect extraterrestrial signals using publicly accessible data. He intends to use the tutorial both in-person and remotely, and is expecting to test it out during Summer 2022 remotely with high school and undergraduate students.

Finally, as part of a unit Mr. L and his BERET+D research mentor developed on weather and space, Mr. L and his physics students launched a weather balloon from their high school. The balloon collected real-time visual and climate data as it ascended into the stratosphere before eventually landing safely. After posting the flight of their balloon online (youtube - https://www.youtube.com/watch?v=Fs67h4uVOzU), other middle school and elementary school teachers in the area have reached out to partner with Mr. L, and to have his students visit their classroom to lead science demonstrations with younger students. Mr. L and Ms. N intend to continue leading the discussion panel and teaching the engineering unit for the remainder of this academic year, and to co-lead field trips for their high school students to several university labs as COVID-19 restrictions ease.

Case 2 - High School Biology/Chemistry Teacher Mr. C

Mr. C, an IST participant from Summer 2021 and teacher from Northern California, contributed to research on a metagenomic approach to examine alternative and sustainable biofuels. As part of their summer research experience, they also collaborated with their research mentor at the Joint Genome Institute (part of Berkeley National Labs) to develop a step-by-step video tutorial for teachers to engage high school biology and chemistry students with data science techniques related to molecular biology, genetics, and biochemistry. The tutorial is designed to help students understand how to use a publicly accessible genomics database developed by the Integrated Microbial Genomes (IMG) in order to closely analyze the gene sequences of organisms that exhibit specific metabolic pathways. Using this database, teachers will be able to support students as they develop their understanding of principles ranging from chemical reactions and stoichiometry, to geology and the rock cycle, to photosynthesis, respiration, and climate change. Currently, Mr. C is developing a curricular unit that guides his biology and chemistry students to:

- analyze genome samples for evidence of metabolic activity from prehistoric core samples
- examine how and why E. coli behaves when it interacts with human metabolic functions
- study how microbiomes within human gastrointestinal pathways change based on nutritional habits
- study how nitrogen fixation pathways can be genetically altered to create alternative biofertilizers
- examine the biochemical pathways present in extremophiles in order to understand how they help sustain marine ecosystems

Case 3 - High School Mathematics/Physics Teacher Ms. S

Participating during both summer 2020 and 2021, Ms. S and her research mentor developed a curricular unit around radiation detection designed to engage students with real-time data from their community, and from around the world. As part of this unit, Ms. S and her mentor introduced high school students to a network of radioactivity sensors (dosimeters) collecting data such as GPS location, altitude, temperature, CO_2 concentrations, as well as Geiger counter readings. The distributed network of dosimeters counts radiation interactions at each location, giving the counts per minute (CPM) averaged over a 5-minute interval. The CPM is converted to a rate of radiation dose that people are being exposed to. Each dosimeter then takes this measurement and sends it to a central server, where it is displayed on a mobile device allowing for real-time monitoring of radiation levels across the network. As part of the unit developed, Ms. S engages her students in statistical analysis using Python coding so they may compare radiation levels from different neighborhoods that are part of the network of sensors.

Currently, Ms. S is helping her mentor's research team to develop the next generation of sensors that are both portable and capable of measuring a broader range of radiation and atmospheric conditions. Ms. S intends to work with teachers at her site, as well as other teachers in the San Francisco Bay Area, to aid them in building their own portable sensor, to help verify its functionality and accuracy, and to deploy them at various school sites to examine the range of variations that exist across the region from the beaches, where it is known that the background radiation can be considerably higher than the geographic average, to the top of local peaks that approach 4,000ft in elevation. The portability of the sensor package will allow the researchers (teachers and their students) to seek out radiation hot spots that may not have been previously identified. Moving forward, Ms. S is developing an engineering unit and citizen science project that supports students in constructing their own portable sensors so they may collect data and contribute to the work at the university.

Case 4 - High School Environmental Science Teacher Mr. K

Mr. K, a high school biology and environmental science teacher, participated in the BERET+D program during summer 2021. As part of this summer research, Mr. K collaborated with his research mentor to look closely at how reducing frictional drag on ocean shipping vessels may help reduce their emissions, as well as their negative economic and environmental impact. As part of his work in BERET+D, Mr. K developed a curricular unit using the engineering models from his summer research to help his students:

- develop testable questions and hypotheses
- differentiate between dependent and independent variables
- identify differences between qualitative and quantitative data, and the value each brings to different contexts
- use statistical analysis techniques to combat false or spurious claims involving data, and to develop expertise in evaluating the credibility of data
- engage in the peer review process
- practice communicating scientific ideas to non-scientific audiences

With the help of his research mentor, Mr. K designed, constructed, and video recorded a demonstration model of how water flows under the hull of a ship both with and without modifications to reduce a ship's frictional drag resistance. Along with this demonstration, Mr. K has students collect qualitative and quantitative data in order to (1) design investigations related to the impact of structural modifications to ships on their emission output, and (2), to use evidence to make claims about how these modifications affect the environment. Mr. K intends to further develop this unit by giving his students more opportunities to develop a set of criteria by which they evaluate scientific claims as part of push towards greater data literacy.

Outcomes - What are the potential impacts of summer research on participating teachers' K-12 students?

We assessed participants' understanding of 1) how to support their students to learn about STEM careers, 2) the importance of engaging students in 21st Century skills in the classroom, and 3) the frequency with which they planned to engage students in the eight NGSS Science and Engineering practices. Teacher participants were asked to rate their agreement with a series of statements related to students and classroom practice on both the pre and post surveys. The statements were taken from two validated instruments (Teacher Efficacy and Attitudes toward STEM Survey (T-STEM), Friday Institute for Educational Innovation (2012) and the Science Instructional Practices (SIPS) survey, Hayes et al. 2017) and included additional questions related to the NGSS Science and Engineering Practices.

Average scores (on a scale from 1 to 5) are shown in the table below for all respondents for the pre and post surveys as well as the 19 respondents who completed both the pre and post survey (matched). On average, respondents' scores were fairly high (above 3.5 on a 5-point scale) on both the pre and post survey. There were only two areas of statistically significant growth shown for knowledge and confidence in engaging students in conversations about STEM careers (with a medium effect size) and how often participants planned to use Developing and Using models in the classroom (with a small effect size). Developing and Using models with students was something that almost all respondents reported that they planned to engage students in at least weekly after their summer research experience. Some items increased and some decreased pre to post with no other significant differences showing that as a group the participants' feelings did not change meaningfully for these areas as assessed by the survey. In the post survey, 100% of post survey respondents agreed with the statement that their summer research/work experience positively influenced their plans to raise student awareness about STEM careers.

Participants' Average Scores for Pedagogical Aspects Related to Teaching STEM Skills

Aspect	**Pre all (n=20)** Mean, S.D.	**Pre matched (n=19)** Mean, S.D.	**Post matched (n=19)** Mean, S.D.	**Post all (n=22)** Mean, S.D.
STEM Careers	3.57, .82	3.50*, .76	4.11*, .71 (*d*=.76)	4.06, .67
21st Century Skills	4.52, .89	4.70, .32	4.64, .30	4.62, .32
Asking Questions and Defining Problems	4.75, .44	4.74, .45	4.63, .50	4.64, .49
Developing and Using Models	3.75, .64	3.74*, .65	4.11*, .57 (*d*=.48)	4.09, .53
Planning and Carrying Out Investigations	3.75, .85	3.74, .87	3.63, .68	3.64, .66
Analyzing and Interpreting Data	4.25, .79	4.26, .81	4.26, .73	4.32, .72
Using Math and Computational Thinking	4.25, .91	4.26, .93	4.16, .83	4.14, .83
Constructing Explanations and Designing Solutions	4.35, .67	4.37, .68	4.21, .63	4.14, .71
Engaging in Argument from Evidence	4.30, .66	4.37, .60	4.37, .83	4.41, .80
Obtaining, Evaluating, and Communicating Information	4.15, .75	4.16, .77	4.42, .69	4.36, .73

* statistically significant difference at $p<.05$ pre to post.

Additionally, participants were asked which of the 21st Century skills were most important by picking their top three choices and explaining why those chose them. Some respondents chose more than three and some chose fewer. As can be seen in the table below, respecting the difference of their peers, making changes when things do not go as planned, setting own learning goals, including others' perspective when making decisions, and working well with students from different backgrounds was important to participants on both the pre and post survey. Setting own learning goals increased in importance for more participants from pre to post summer. Lead others to accomplish a goal and choose which assignment out of many needs to be done first was less important overall to participants on the pre and post survey.

21st Century Skills that Participants Reported as Most Important for Students

Skills	**Pre Survey (n=19)**	**Post Survey (n=22)**
Lead others to accomplish goal.	2 (4%)	1 (2%)
Encourage others to do their best.	4 (7%)	6 (9%)
Respect the differences of their peers.	9 (16%)	8 (12%)
Help their peers.	6 (10%)	4 (6%)
Include others' perspectives when making decisions.	5 (9%)	6 (9%)
Make changes when things do not go as planned.	9 (16%)	11 (17%)
Set their own learning goals.	7 (12%)	11 (17%)
Manage their time wisely when working on their own.	3 (5%)	4 (6%)
Choose which assignment out of many needs to be done first.	2 (4%)	3 (5%)
Work well with students from different backgrounds.	10 (18%)	11 (17%)

Participants were asked to choose one or two of the eight NGSS practices they planned to use the most and which they planned to use the least with their future students. As can be seen in the table below, Asking Questions and Defining Problems remained the most reported practice to be used on the pre and post survey by nearly three quarters of respondents. Planning and Carrying Out Investigations was reported as a practice that overall would be used less often both prior to and after the summer, the most often reason given was that it was a long process that would take a lot of time. Using Mathematics and Computational Thinking was a practice that more participants said they would use more often after the summer. Developing and Using models was reported as a practice that would be used less often on both the pre and post survey, the most often reason given was lack of knowledge of how to engage students in this practice.

Science and Engineering Practices that Participants Planned to Use Most and Least in their Future Classrooms

Science and Engineering Practices	**Pre Survey (n=20) Use Most**	**Pre Survey (n=20) Use Least**	**Post Survey (n=22) Use Most**	**Post Survey (n=22) Use Least**
Asking Questions and Defining Problems	13	-	14	1
Developing and Using Models	-	5	1	6
Planning and Carrying Out Investigations	1	9	1	8
Analyzing and Interpreting Data	5	1	4	-
Using Mathematics and Computational Thinking	2	3	5	3
Constructing Explanations and Designing Solutions	2		2	1
Engaging in Argument from Evidence	4	2	3	2
Obtaining, Evaluating, and Communicating Information	4	2	2	3
None of the above	-	-	-	-

In the pre survey, participants were asked "how do you see your summer research experience impacting how you engage your students in the above practices in the future?" The responses centered around how their research experiences would both give them important experiences engaging in the practices as well as insights into ways to engage their students in the practices. All but one of the responses on the post survey indicated that the summer experience would have an impact on how they engaged students in the NGSS Science and Engineering practices and research in general. Some participants relayed how their experience would help them talk about the research process more confidently and knowledgeably. Others discussed how working with data has given them more comfort in helping students work with data.

Opportunities for Teaching & Mentoring

Research mentor contributions and perspectives

As part of BERET+D, more than 40 research faculty have mentored our participants in the first two years of the program. As part of their work with PSTs and ISTs, research mentors:

- supported participants as they work with large data sets
- worked closely with participants to develop research questions, and to design and carry out an investigation
- met regularly with participants to monitor progress, offer support, and provide feedback

Research mentors were also asked to include, when possible, participants in the day-to-day activities of a research lab such as attending and presenting at lab meetings, reading and discussing publications in the field, preparing and maintaining materials, and participating in any safety training or protocols required by the lab. In all cases, participants collaborated with and learned from multiple researchers (postdoctoral fellows, graduate students, etc…) within each lab, again emphasizing the community of practice BERET+D seeks to foster (Wegner, 1998). Though successful in previous projects, we were particularly interested in gathering feedback on this format during 2020 and 2021 as nearly all work was completed remotely due to COVID restrictions.

Overall, research mentor feedback was positive with every mentor reporting success in maintaining regular communication remotely through either Zoom, Google, or Slack platforms. Research teams were able to share results, troubleshoot problems in coding, and decide on necessary shifts to experimental designs throughout the summer experience. Without being able to travel, some researchers also scheduled meetings with experts from around the world who were also eager to support participants. Perhaps because much of the research involved data science, and could be completed remotely, most mentors reported success in completing an investigation during the summer program. Aside from the positive feedback, there was predictable difficulty in daily monitoring of participants that was often present during previous iterations of this project. Many mentors described the lack of in person interaction as challenging, and mentioned that they looked forward to shifting back to in-person work during subsequent summers. Specifically, mentors reported the need for more "moment-to-moment communication" in order to have "informal conversations" to help participants with questions that inevitably arise and could be resolved quickly. This type of interaction occurs regularly in most in-person workplace settings, but is less common in remote settings that lack a structure for continual dialogue. Though we plan to shift back to in-person participation in the coming summer, we will also consider working with research mentors to develop a more robust communication structure in the event that remote work is required, and also because having multiple ways to communicate may be useful for various in-person contexts as well.

Benefits of teacher and undergraduate pairs

Through the first two years of BERET+D, we have had 5 ISTs working with one or more PSTs in the same research lab. As part of a pairing, ISTs and PSTs complete their own distinct research project under the guidance of a research mentor, while also collaborating to design either a single lesson plan (in the case of PSTs) or a curricular unit (in the case of ISTs) based on their research. What was often noticed and shared in survey feedback is that the PSTs appreciated the expertise and perspective that ISTs had regarding classroom contexts, systemic constraints, and best instructional practices. ISTs appreciated working with students who could help them "acclimate to the university setting", "stay on top of new learning theories", and reported in nearly every case "feeling re-energized by someone so eager to teach STEM".

Data Science Showcase Promotes Career Awareness

During Year 2 of the BERET+D program (2021), all IST and PST participants, research mentors, and CalTeach faculty, were invited to attend the Data Science Showcase, a virtual, program-wide event co-developed by faculty from UC Berkeley's College of Engineering, the Division of Computing, Data Science, and Society, as well as BERET+D. This virtual event fostered collaboration and conversation around problems of practice in wide ranging data science contexts including, mathematics, science, engineering, computer science, public policy, education, economics, and healthcare. Additionally, data science experts introduced participants to several ongoing data science projects as a way to discuss typical skills to prepare high school students for careers in data science. This annual event for BERET+D has the flexibility to be offered virtually or in-person, allowing us to (1) increase participant awareness of the practices in which data scientists typically engage; and (2) invite a wide audience, including local high school and community college students and their instructors.

Together, the research experiences, concurrent curricular development, and ongoing mentoring and professional development events work collectively as a whole to create a rich summer research program for teachers that has the potential for far-reaching impacts for K-12 students.

Conclusion

Engaging pre-service and in-service teacher participants in full-time STEM summer research projects focused on data science resulted in developing their understanding of data science as a discipline and its associated research practices. Moreover, teacher participants were able to design and implement rigorous curricula for their own classrooms, supporting their middle and high school students to learn engineering design principles and data science approaches, leading to increased awareness of the importance of these fields and to consider them for potential careers. During the first two summers of the BERET+D project, teacher participants completed over forty data-science related projects, developed over thirty K-12 data-science related lesson plans in math, science, and engineering, and created six classroom-ready and publicly accessible (teachengineering.org) curricular units showcasing data science. In previous studies, Helix et al. (2022) used open-ended prompts and poster presentations to reveal undergraduates, including pre-service teachers, develop an understanding of their researchers projects. Findings suggest that undergraduates grow in their use of disciplinary evidence and in explaining the societal relevance of their work over time, but that they incorporate only minimal discussion of prior research into their reflections and presentations. Here, our evaluation shows that teachers engaged in data science-related summer research come to view that data science as important and essential in K-12 curriculum, data analysis is a critical and useful skill for youth, and data science aligns closely with the science and engineering practices called forth by NGSS. Though constrained by work-from-home restrictions due to COVID during the first two years, we highlight how participants described their experience as positive and valuable, particularly in conceiving of ways to engage young learners with data-science through remote instruction.

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