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Reinvigorating Energy Teaching via Research with Engineers (Evaluation)

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Abstract

This Evaluation paper describes the preliminary findings for the first two years of a 3-year project involving high school science teachers at a metropolitan-based university. The project's predominant focus relates to *energy*, as a unifying theme across scientific and engineering domains. The project's overarching goals were to: (a) deepen high school teachers' understanding of engineering principles, practices and design, (b) support the development of STEM-integrated curriculum aligned with the Next Generation Science Standards, and (c) to enhance ongoing collaboration and interchange among university faculty, local schools, and industry-based personnel. Over the course of a 6-week research experience, each cohort of teachers (20 teachers in the first two years, with 10 more forthcoming in year three) was paired with an engineering faculty member on one of five "energy-focused" research project (2 teachers per project). In addition to participating in a research project first-hand, teachers also received support developing a curricular unit for the upcoming school year that incorporated their learning from the summer research experience.

1. Introduction

In 2009, a Carnegie Foundation commission of notable national leaders, educators, and researchers commenced the establishment of the NGSS. The primary factor driving this endeavor was extensive data suggesting the U.S. system of science (and mathematics) education has been performing well below numerous fellow OECD nations [1]. The committee identified several deleterious results if this trend continued, including the reduction of the United States' competitive economic edge. Stated benefits of improved science and technological literacy included the provision of essential preparation for all careers in the modern workforce. Moreover, without a flourishing scientific and engineering community, young people may not be motivated to dream of "what can be," and might have inadequate motivation to become the next generation of scientists and engineers that can address persistent national problems including national and homeland security, health care, the provision of energy, the preservation of the environment, and the growth of the economy.

The NGSS, built upon The Framework for K-12 Science Education, explicitly integrate science and engineering, something previously done in only 12 states [2]. Explicitly integrating engineering practices and aspects of engineering design across the K-12 spectrum has broad aims spurred by national reform documents and is justified by economic and/or national security interests [3]. Integrated learning experiences continue to be promoted because they impact career choice, increase student achievement [4] and harness students' curiosity by providing authentic, design-based, cooperative learning experiences [5]. Using the NRC framework as a model, NGSS standards were established so that each could be fully realized via combination of three distinct and equally important dimensions (3D): 1) Disciplinary Core Ideas, 2) Crosscutting Concepts, and 3) Science and Engineering Practices. Disciplinary Core Ideas (DCIs) are fundamental scientific themes that have the greatest significance across four domains: Physical Science, Life Science, Earth/Space Science, and Engineering. Crosscutting Concepts (CC) help students explore connections across these domains and are intended to assist students in developing a comprehensible and scientifically based view of the world around them. Science and Engineering Practices (SEPs) encompass the typical methods and/or tools that scientists use to investigate and engineers use to design and/or build. Students utilize SEPs to supplement their knowledge of DCIs and CCs.

Classroom instruction aligned to the NGSS now includes engineering practices and aspects of engineering design, which have risen to the same level as scientific inquiry. Teachers and students alike may be unprepared to engage in collaborative learning environments of this nature, particularly when engineering design is featured. Engineering-focused learning experiences will require students to engage in new processes and procedures while talking in ways that may differ from their preferred method of communication. The language of science, and the theoretical underpinnings that promote its use as a process for generating knowledge (or in the case of engineering solutions) are unfortunately seldom articulated in K-12 classrooms due to the dearth of relevant experience most teachers possess [6].

2. Project Purpose & Description

With the program's overarching theme of energy, we aimed to: (a) deepen high school teachers' understanding of engineering principles, practices, and design, (b) support the development of STEM-integrated curriculum aligned with the Next Generation Science Standards (NGSS), and (c) to enhance ongoing collaboration and interchange among university faculty, local schools, and industry-based personnel. The purpose of the program evaluation was both formative and summative, aiming to improve incoming cohorts' experience, and report on the impact of the program on participants. We hypothesized that teachers would a) have an enhanced knowledge and experience conducting engineering research, b) have strengthened knowledge of and ability to plan and deliver curriculum related to engineering design. The official title of this particular RET experience is titled *Reinvigorating Energy Teaching via Research Experiences for Teachers* – predominantly termed *RET via RET* by project administrators and participants. The project takes place over a 6-week summer period with 10 metropolitan high-school teacher applicants selected prior to commencement.

This RET via RET project incorporates a robust mix of energy-aligned research, professional development, and teacher curriculum development and modification. Five different research projects included in the program, each assigned with a faculty mentor, are respectively aligned with various energy themes, including:

1. **Energy Storage**: assessment of the performance on the PI's (patented) heat-pipe augmented solar space heating system using internal storage media.
2. **Energy Efficiency**: energy performance analysis of the XXXX Phoenix House test bed (former solar decathlon participant).
3. **Energy Transfer**: experimentation in sky radiation for passive cooling.
4. **Energy Conversion**: studying the effect of working temperature on all-solid-state battery performance.
5. **Renewable Energy**: research pertaining to harvesting geothermal energy for building space conditioning.

While each of the five research projects (2 teachers per project) are focused on potential augmentation and emerging technologies within the energy sector, program professional development (PD) is more centered on current state of the art regarding energy. Program PD is primarily focused on further energy edification and engineering design thinking. Sample features of energy edification PD include training sessions with (project partner) the National Energy Education Development (NEED) project in addition to sessions with RET via RET personnel. The rigors of research, learning, and curriculum development are supplemented weekly with energy-aligned industry tours. The majority of these tours are served by the metropolitan utility (LG&E), hosting four of the six industry tours for both years of the project thus far. Additional industry tours have included the National Guard, a bourbon plant, and a chemical processing plant. The engineering design process (EDP) is introduced to project participants early in the experience, and further practice, integration, and application of engineering design thinking is explored via select simulation of aspects of the PI's ENGR 111 first-year course [16-22].

The first week of the RET via RET project serves as an orientation for the remaining five weeks, and includes industry presentations, introduction to the EDP and NGSS, background and facility tours for each of the five research projects (followed by respective participant ranking in research project preference), and the first LG&E tour. Participants engage in no less than a total of 42 hours of research experience over the project duration, and several morning and/or afternoon sessions during the final week and a half of the project are left to teacher discretion in conducting more research or working on curriculum development. The RET via RET program culminates with respective participant team presentations on research experience(s) and the developed curriculum that will be integrated into the upcoming academic year. Finally, also scattered within the 6-week program are program evaluation sessions, much of which are discussed in the greatest detail within this article.

3. Literature Review

Anderson and Moeed [7] recently reported that teacher professional development situated within a professional (i.e. scientific/engineering) workplace can produce "sustained" changes in teachers' beliefs, in large part because they develop a systematic understanding of the nature of science and scientific investigations. Teacher experiences working with professional engineers engaged in empirical research in a laboratory setting are likely limited. Findings from studies investigating the outcomes of teachers engaged in research opportunities with scientists have reported research experiences help teachers understand the knowledge-generating process of science via immersion in the culture [8]. In addition to participating in a culture of science, teachers also reported learning about new techniques central to the data collection process of a specific discipline, as well as how to enact "creative alteration" of experimental procedures [8]. Importantly, teachers do not always recognize and understand the implicit assumptions guiding scientists thinking during an investigation. McLaughlin and MacFadden [9] reported that it was beneficial for teacher participants to be involved with partnering scientists' discussions/arguments wherein they had to "discuss emergent theories and conflicting evidence" (p. 276) because it helped teachers recognize the inherent messiness of science. The project aims to foster significant progress towards successfully addressing these challenges in the (host institution) University of Louisville metropolitan area.

An attempt to incorporate each and every possible scientific topic into an RET-based project is both unwarranted and unrealistic. Yet the topic of energy represents a unifying theme across essentially all scientific domains. In fact, energy is the only major scientific construct that appears as both a DCI and CC within the NGSS. Energy is a DCI since it describes physical interactions within the vast majority of systems; the NRC framework has specified four major dimensions relating to energy as a DCI. The NGSS identified energy as a CC because it crosses all disciplinary scientific boundaries: living, non-living, natural, and human-designed. Indeed, energy is needed in some capacity to make sense of most scientific phenomenon. Energy as a CC provides an organizational framework for student learning capable of connecting long-lasting, unifying ideas across the disciplines. Also, because the consequences of our global energy resource supply and use will affect fundamental aspects of our lives, there has been a campaign from the U.S. Department of Energy to strive for everyone to become energy literate. In the past, teachers have failed to help students identify energy's ubiquitous presence across scientific disciplines, likely as a result of energy remaining in the backdrop of science instruction. Teachers will inevitably need support in their own understanding in order to ensure energy is successfully incorporated across a student's learning experience. In addition to providing content knowledge support, teachers will also need ideas and inspirations capable of supporting a change in beliefs [7], of which this RET experience is designed to support.

4. Rationale

It is of the authors' opinions that the integration of engineering design principles is critical and should be present throughout the RET experience, since many STEM-based careers in the modern world exist within the world of engineering [10]. Science and engineering, while containing many similarities, vary fundamentally in terms of epistemological features. Scientists focus on generating new and verifiable knowledge, while engineers strive to provide solutions to problems. Data, as a form of evidence for making claims (for science) or designing solutions (for engineering), plays a critical role during every scientific pursuit (and the engineering design process). Scientists utilize data to explain and validate observed patterns in the natural world via a socially accepted process [11]. Engineers, however, utilize data as means for assessing the performance of a designed solution against a set of criteria and constraints defined by the problem and/or client [12]. As science classrooms begin to take on and enact practices similar to that of real-world engineers, it is important to draw attention to the differing ways data gets utilized as students collaboratively engage in the engineering design process. As previously alluded to, engineering design is considered a "central practice" for students as they engage in discipline-specific practices intended to mirror the work of engineers. In order to be successful students must therefore enact "systematic practices" that produce designed solutions to identified problems.

5. Research Design

This 3-year project involving high school and middle school science teachers was hosted at the University of Louisville. The project was themed *energy*, unifying the science and engineering fields. During the six-week research experience, 10 new teachers each year were assigned an engineering faculty member on one of five energy-themed research topics, with two teachers per project. Teachers also received support for developing curricula for the upcoming school year that incorporated their research experience, in addition to engineering design integration, into their teaching practices, with the NGSS standards in mind. This study was approved by the Institutional Review Board.

Our primary objectives were for teachers to become more familiar with conducting engineering research and develop and implement engaging curriculum aligning with NGSS to their students. Therefore, evaluation focused on: A) the quality and value of the engineering research experience (objective 1); B) the quality and value of the program in strengthening teachers' applied curriculum integrating engineering design (objective 2); and C) the quality and value of supplementary experiences (site visits to industry partners, NEED energy curriculum sessions etc.) (objectives 1 and 2).

Teachers were selected based on their past teaching experiences and classroom contexts for maximum descriptive power [13]. For recruitment, we targeted schools in the surrounding county with existing collaborative relationships. The county is a large school system in a mid-size, metropolitan area in the southern United States. As the surrounding county represents a linguistically and culturally diverse region that has historically served refugees from Latin America, Asia, and the Middle East, the efforts of the teachers in our program are aimed at serving students from diverse and marginalized backgrounds and improving their science education experience.

We used a utilization-focused evaluation approach [14-15] to gather and report both quantitative and qualitative data. For quantitative analysis, surveys were administered to teachers to assess the three aims of the study: learned concepts of engineering, curriculum aligned with NGSS, and enhanced collaborative experiences. Qualitative techniques included thematic coding and cross-case comparisons of yearly focus groups, open-ended survey items, and semi-structured interviews in the academic year following the six-week summer experience.

6. Instruments

6.1 Semantic Differential Scales

At the end of daily activities, participants completed session evaluations that elicited participant ratings in four domains. Items were rated on seven 5-point semantic differential scales. These questions were asked about the energy research experience, engineering design curriculum knowledge of and readiness to teach their science standards, and their supplementary program experiences. Each of these measures were used iteratively to improve each subsequent year of the project.

The engineering research experience was evaluated at all three time points. For the pre and post scales, the scale ratings of the engineering research experience were grouped into two larger categories: (a) expectations (items *clear, realistic, organized*) and value (items *challenging, useful, engaging, relevant*). Items for the mid-scale slightly differed, as these assessed partial progress through the program (items *helpful, well spent, recommend, engaging, valuable*). Teachers' knowledge of engineering and the engineering design process in the science standards was assessed both pre and post (items *clear, realistic, relevant, will improve/is stronger*) while their readiness to teach energy and engineering was assessed at all three time points (items *clear,* *realistic, challenging, engaging, relevant*), with mid evaluation slightly different (items *anticipated, smooth, interesting, integration, relevant, satisfied*). Lastly, teachers' supplementary experiences were assessed only at the mid timepoint. The questions assessed the teachers' value of the supplementary experiences (items *helpful, well spent, recommend, engaging, valuable*). The value of the suite of supplementary experiences was assessed mid-program with a question structured as a semantic differential scale, primarily because the bulk of these supplementary experiences had been completed by mid-program since the latter portion of the program emphasized a combination of engineering research and curriculum development.

6.2 Open-Ended Questions

Participants also responded to several open-ended questions at the end of the semantic differential scales during all three timepoints. The questions were consistent across timepoints and cohorts, first asking, "What has been the most satisfying so far, and why?" and then, "What would you change, if anything about your project experience and why?"

6.3 Focus Groups

The investigators also ran focus group sessions to gain more qualitative information about the participants' experiences in the program. For cohort one, the participants had focus groups at all three timepoints, while cohort two only had a focus group at the end of the program. This was due to an understanding that the focus group provided the most valuable feedback at the end of the six weeks with the full experience having been completed.

For cohort one, the focus group questions slightly differed based on the participants' progress through the program. For example, at the pre timepoint, they were asked, "Based on your first 3 days of this summer project, what are your reactions and opinions related to the potential for this summer experience to meet your goals and reasons for choosing to be here?" and "What other initial reactions and feedback would you have for the project team related to the startup of this project?" By the mid timepoint, the participants were asked, "How would you characterize your overall experience so far?" and "What questions or additional information would you like to have at this point in your summer work?" At the post timepoint, the focus group questions were, "If discussing your summer experience with teacher colleagues, what are some key aspects of the program you would share with them? These can include positive or negative or unexpected experiences." and "Is there anything else you would like to share regarding your involvement in the RET project?" Only the questions from the post timepoint were used for the single focus group that cohort 2 did.

7. Data Analysis

Analysis includes (a) longitudinal analysis of qualitative data across the three time points per cohort: and (b) single within-group pre-mid-post evaluation of group level change over the course of the program per cohort. Qualitative analysis includes theme identification for the open-ended questions, and for focus group interpretation. Results are reported here for the first two cohorts only, as the final cohort has not yet completed the program.

8. Results and Related Discussion

8.1 Quantitative Results

8.1.1 Engineering Research Experience

At all three time points, both cohorts rated each aspect of energy research positively (>3, since 3 = neutral), the one exception being easiness. However, we conceptualize the ideal easiness score as a 3, as that item asks teachers to rate the energy research experience on a scale from *challenging* to easy. Ideally the research experience would have been challenging enough to be engaging and therefore a learning experience (not too easy), but also accessible to achieve (not too challenging). For both cohorts, all ratings increased from pre to post timepoints, barring *useful*, which decreased by .4 points. This may be because the teachers had already gained all that they could have from the energy research experience by the end of the program, lowering their perception of its utility.

Generally, cohort 1 had strong positive responses to all aspects of their engineering research. The only exceptions are *clear* at the pre timepoint, and *progress* at the mid timepoint. A medium *clear* score at the pre timepoint is understandably weaker given that this pre-measure was on day 3 and the teachers were still learning about the summer program, and a medium progress score is understandable because teachers are not expected to have made significant progress in their engineering research by week 3, when the mid timepoint measure was given.

Cohort 2 is similarly largely positive, exhibiting a similar pattern to cohort 1 in the lowest scores being *easy*, which we would ideally want around 3, and *clear*, which we explained above to be an understandable finding.

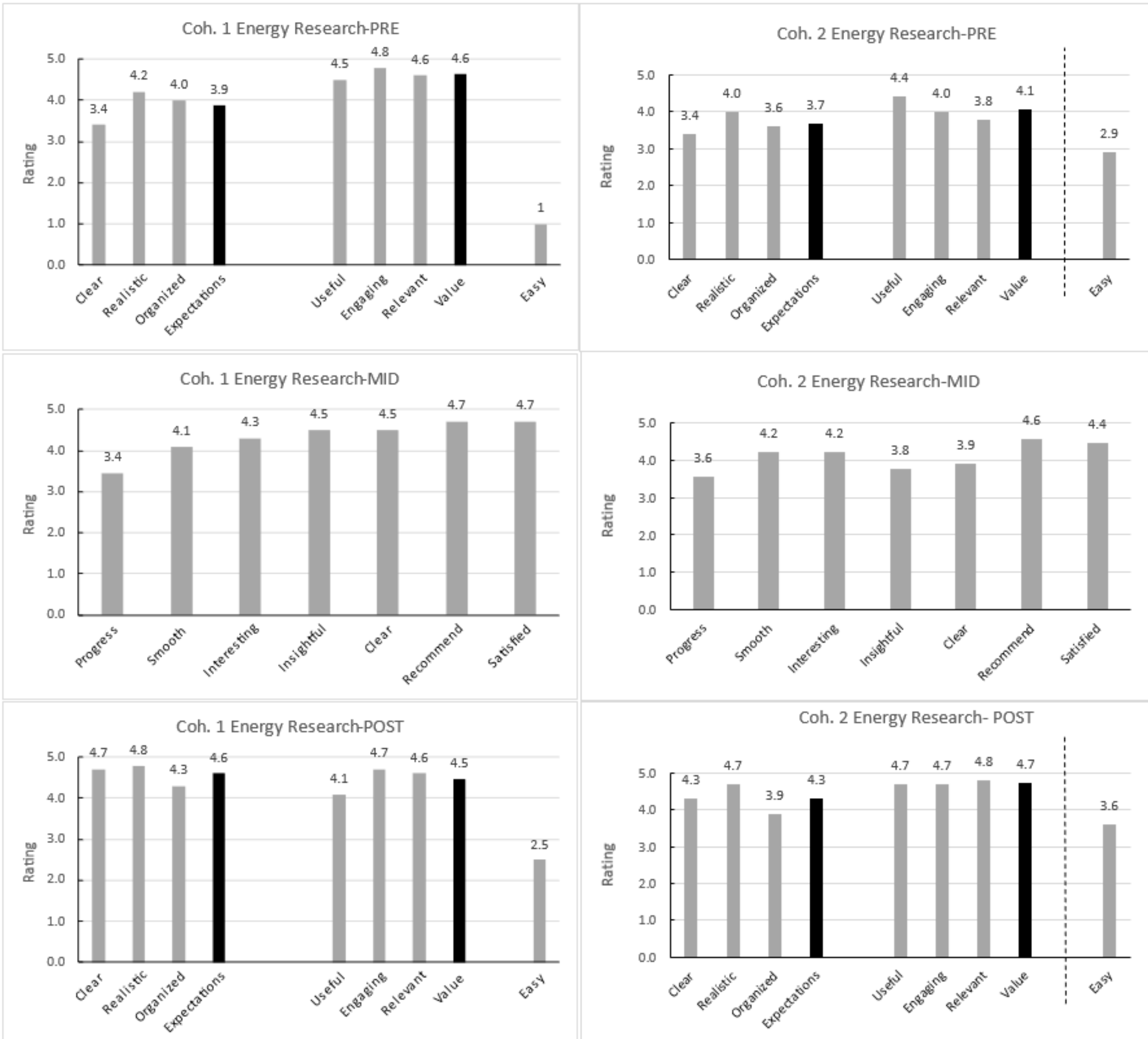

Figure 1. Respective cohort ratings of quality of engineering research experiences.

8.1.2 Curriculum and Pedagogy

Figure 2 demonstrates that teachers in both cohorts improved in their understanding of engineering design across all domains, barring *will improve/stronger understanding* for cohort 1, which shows their confidence at the pre timepoint that their understanding would improve, and their still high rating that they did have a stronger understanding by week 3 (score = 4.4). The largest increase in engineering design for cohort 1 was in their *clarity* of what the engineering design standards call for. Cohort 2 increased in all domains, and did so most significantly in *clarity* and *relevancy* with a .9 score increase, emphasizing that engineering design and its relevance to their teaching became drastically better from week 1 to week 3 of the summer program.

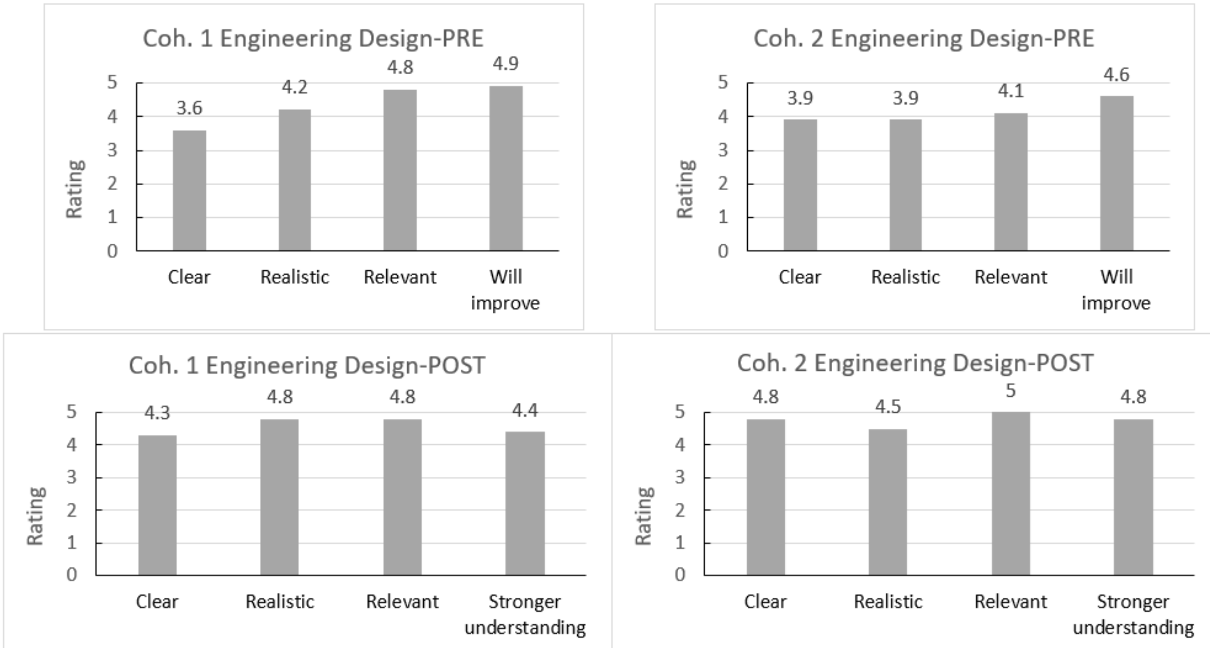

Figure 2. Respective cohort ratings of knowledge of engineering design standards.

Shown in Figure 3 are scores for cohorts 1 and 2 in their confidence teaching energy and engineering design across pre and post timepoints, as well as curriculum development during the mid-timepoint. Similar to the evaluation of their energy research, the easy item is ideally a score of 3, to set an appropriate difficulty level that engages teachers. Cohort 1 reported an increase or stability across domains in their ability to teach energy and engineering design, right at the appropriate difficulty level with their pre and post timepoint scores (2.8 and 2.9, respectively). This cohort was 100% confident that teaching energy and engineering design was *relevant*, with scores of 5 at both pre and post timepoints. Cohort 2 also exhibited increases across domains for these questions, with the most notable escalation in clarity, growing from 3.9 in pre to 4.7 in post. Strong ratings were also reported across all aspects of the program related to supporting curriculum development at the midpoint of the summer for both cohorts.

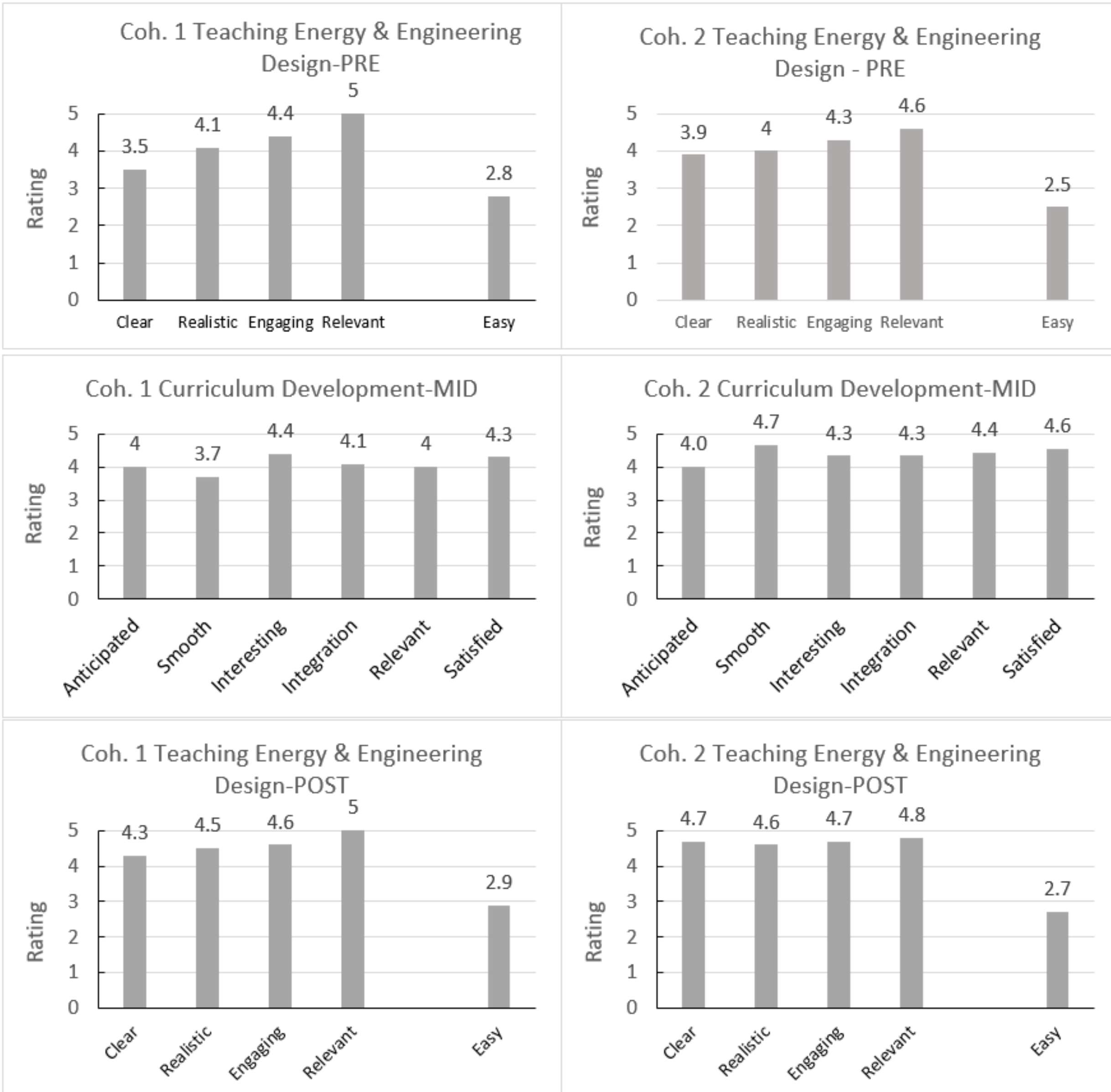

Figure 3. Respective cohort ratings of readiness to teach energy and engineering design.

8.1.3 Supplementary Experiences

Cohorts 1 and 2 similarly highly rated their supplementary experiences positively, with no noticeable distinguishing domain in either cohort. For both cohorts, the scores were at 4.5 or above across all items.

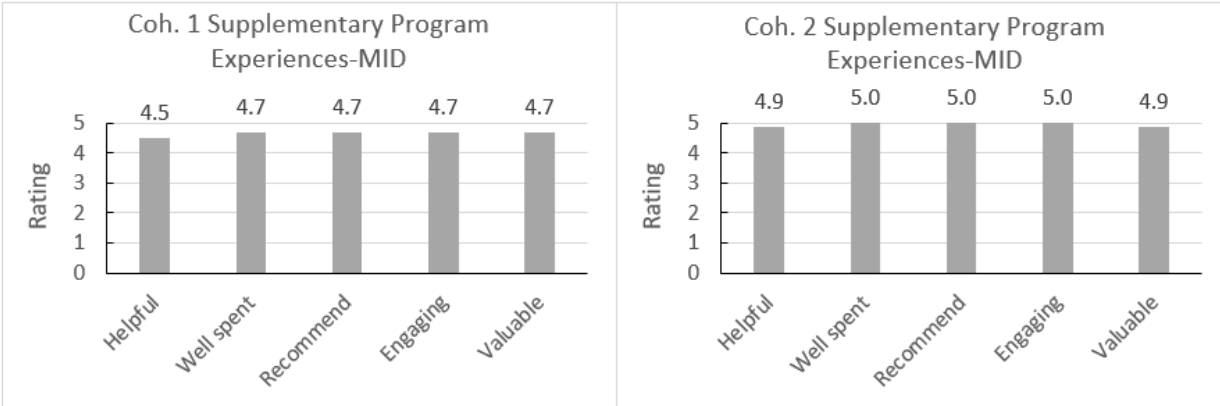

Figure 4. Respective cohort ratings of supplementary experiences.

8.2 Qualitative Results

8.2.1 Open-Ended Questions

The first cohort highlighted different experiences as the best or most satisfying from the three different time points. See Table 1 for identified statements and how many participants endorsed each statement. For example, the most teachers endorsed active learning/engagement as the best experience during the pre-timepoint, while the LG&E tours were most mentioned during the mid timepoint, and research experiences were highlighted in the post timepoint. The participants listed several different reasons for choosing the best or most satisfying experiences, many surrounding motivation, engagement, and learning. Cohort one also gave some constructive feedback, including less NEED sessions, more focus on curriculum guidance and NGSS, which the investigators took into their program administration for cohort two.

Table 1. Cohort One Best Part of Experience and Suggestions for Change.

	Best or Satisfying	# responses	Rationale	Change	# responses
PRE	• Engagement & active learning (including ENGR111) • Research Projects • Pedagogy/curriculum • LG&E • People	4 2 2 1 1	• Motivating, fun doing ENGR111, inviting atmosphere, challenged • Excitement, incorporate into teaching • importance of CCC, useful • new ideas and info • invested and interested	• Fewer NEED sessions or time • More NGSS exploration • More about research projects • More clarity about curriculum expectations • Nothing	3 3 3 2 1
MID	• LG&E tours • Hands-on research • College eng student experiences • Curriculum development • Passion of project personnel	6 5 1 1 1	• Engaging or fascinating or fun • Learning new things • Learning new things for oneself • Effective expert guidance	• Fewer NEED sessions • Better understanding of research project at beginning • Guidance for curriculum • Begin research sooner • Streamline research • More processing of field trips	4 3 3 2 1 1
POST	• Research • LG&E tours • ENGR111 experiences	8 6 1	• Learned a lot, accomplishment • Engaging = 2 • Ideas for own classroom teaching	• Guidance on curriculum • Reduce time on NEED • Less KPPL	5 4 2

Note: One participant may endorse more than one statement

Cohort two similarly endorsed different statements across the three timepoints, as found in Table 2. Some common statements across the program include working with others, the field trip and

LG&E experiences, and learning more about energy. The participants had several different reasons for listing these best experiences of the program. While the rationale varied, some common statements were enjoying collaboration, learning for learning's sake, and learning what to apply to curriculum and classroom teaching. This cohort had some suggestions for improvement, including wanting more communication before the start of the program, starting research earlier, and getting more clarity on some different topics. It is notable that many participants noted no suggested changes to the program at both the pre and mid timepoints. It is also notable that comments about needing more support on curriculum development were not nearly as frequent as cohort one, as the investigators pointedly changed the program schedule to address this constructive feedback from the first cohort.

Table 2. Cohort Two Best Part of Experience and Suggestions for Change.

Best or Satisfying		# responses	Rationale	Change	# responses
PRE	• Intro to engineering design & skills (process overview) • Working in teams/with people • LG&E presentation(s) • Generic "new ideas"	5 3 2 1	• Enjoying the company/collaborating • Can apply work directly to the classroom • Exposure to new experiences • Get an idea of upcoming things	• More overview or pre-project communication • Nothing • Less lecture/sitting • Specifics of research project detailed	4 3 2 1
MID	• Field trips/LG&E • Engineering research and design • "Variety of things"	6 2 1	• Learning for learning's sake • Learning applicable things for the classroom	• Noting • Getting to actively doing research earlier • More clarity on expectations or project • More clarity on curriculum	4 2 2 1
POST	• Field trip experiences • Learning activities to use in the classroom • Learning about energy in general • Research experience	7 2 2 2	• Can apply to own curriculum/more informed about energy for students • Added opportunity for student field trips • Learning for learning's sake/informed citizen • Valuable teamwork experience in research • Feel up to date on recent research/technology	• Start earlier (schedules, help on research data, example presentation) • More hands-on research experiences • Spread out on LG&E tours (later in program) • Too much time on curriculum • Skip bourbon tour • Get paid on time	4 3 2 1 1 1

Note: One participant may endorse more than one statement

8.2.2 Focus Group Results

For cohort one, focus groups were conducted at all three timepoints:

Pre: asked about initial impressions of the program on day 3. Three themes emerged that were shared amongst participants:

1. *Anxiety reduced.* Although some indicated that they were initially anxious or unsure if they would be successful in this summer program, they all shared that the first few days of the program were effective in allaying their anxieties and making them look forward to their upcoming experiences.
2. *Looking forward to research.* Several teachers expressly indicated they were looking forward to learning new things for themselves in their research projects with UofL mentors, and were also anticipating learning ideas and approaches to share with their future students about what engineering research is like.

3. *College engineering experiences*. A third theme that emerged is that a number of teachers particularly valued their experiences with the ENGR111 course sampling (a component of professional development related to engineering design included select sampling of the college's first-year introductory course in engineering fundamentals, ENGR 111). Knowing what college engineering freshmen were expected to know/do, and directly experiencing some of that themselves, was valued for helping them to be better situated for preparing their high school students who may be interested in pursuing a STEM college career.

Mid: Most of the feedback from the midpoint focus group was very positive about their experiences to date. In addition to the many overall positive comments, there were two specific aspects they emphasized as particularly positive, and three aspects of the program they articulated as possible changes to consider.

1. *Research mentors helpful*. The engineering research mentors, and particularly the project PI BLINDED, were specifically identified as helpful, passionate, approachable, and engaging partners in the work.
2. *LG&E tours well-received*. The other specific feature that multiple teachers highlighted were the LG&E tours – informative, engaging, new things to learn, and passionate presenters.

The final three aspects were suggestions to consider for future changes.

3. *Less relevance for biology teachers*. The two biology teachers in the group commented that much of the material seemed less relevant for the life sciences they teach, and suggested considering either adding a bioengineering project if possible, or if not perhaps being clearer in the announcements about the best fits being physics and chemistry.
4. *More upfront info on research projects*. Several suggested that it would have been helpful to have more information on the particular research projects earlier, especially before they are asked to identify their preferences. Suggestions included maybe some short (few minutes) intro videos or overviews presented on day 1.
5. *NEED sessions can be reduced*. While many teachers found value in the NEED sessions, a number of them commented that they became redundant to some extent and that they would prefer spending more time on their research projects, including starting earlier on the research.

Post: Given very broad interview prompts, teacher focus group interviews at the end of the project coalesced into three primary themes.

1. *Enhanced understanding for teaching engineering design*. Teachers enthusiastically endorsed statements that this project was very helpful in support of their ability to teach engineering design. The program experiences were described as, "absolutely needed for K-12 teachers to teach engineering" and that [prior to the program] "I would never have thought it could be this easy to incorporate engineering." Teachers spoke about their stronger understanding of the need to be more intentional about incorporating engineering design, and that this program underscored that it is better to focus more on the skills and thinking that students need rather than content-only.
2. *Research experiences were invigorating*. Teachers shared that they found the engineering research experiences "invigorating" and that it brought "fresh excitement" to their

understanding of engineering. They found the research experiences to be "fun and cool" and expressed that they found themselves learning lots of new information for themselves. They also explicitly emphasized the helpfulness, enthusiasm, and approachability of the engineering research mentors which made the overall research experiences so enjoyable and productive.

3. *Keep LG&E tours*. Teachers agreed that the suite of LG&E tours were very enjoyable and productive for sharing new ideas and new information. They explicitly mentioned the enthusiasm of the LG&E presenter Aron as one key feature in making this aspect of the program strong.

For cohort two, focus groups were only held at the end of the program. This was due to the appreciation of giving participants the opportunity to mainly give feedback with the entire program behind them. The focus group questions included what they would share with colleagues about the program, and broadly for any other comments. Several themes resulted from both questions, endorsed by various participants:

Post: What they would share with colleagues:

1. *A valuable use of time.* The teacher participants mentioned that they learned a lot in 6 weeks, that it was fun, and great to be able to engage in "real engineering research."
2. *Prepared to teach about engineering*. The teacher participants explained that they felt unprepared to teach engineering before starting the program despite that being a part of the state's standards. The program bolstered their confidence for teaching engineering.
3. *Deepened background knowledge of engineering*. All teacher participants talked about no matter their starting point, they learned more about engineering in general, particularly from the LG&E series which taught about the generation and distribution of energy for society to function.

Other broad comments included:

Positive

1. *Valuable research experiences*. It was interesting to build on ongoing work of the faculty, in some cases on projects prior teachers had engaged with. Nice to have a peek at the longitudinal nature of research.
2. *Relating the research experiences to incoming engineering students*. The experiences relating to how incoming university engineering students were experiencing the engineering design process (in the course ENGR111) were specifically cited as helpful for them to better understand what they might do to help high school students gain a similar perspective on the field.
3. *Intentionality of curriculum incorporation of engineering*. Several emphasized how this program has helped them consider how to be more intentional about incorporating engineering design thinking across their science curriculum rather than thinking of it as a stand-alone experience.

Constructive feedback

1. *Pre-program orientation meeting*. Participants suggested inviting them to a spring (before summer starts) orientation meeting to get an overview of upcoming research projects,

including maybe sharing prior related presentations of what prior teacher groups did. Can also provide a few papers to read that can help teachers get up to speed a bit before summer starts (can make it optional). This approach can help teachers be ready to begin the actual research and data collection parts of their summer work earlier, especially important given the short time frame of 6 weeks.

2. *Spreading out LG&E field trips.* Perhaps shift some of the LG&E field trips to later in the summer so that more time to engage on own research projects could start earlier. Also, for those projects that need to collect data over a period of time, this would allow for earlier data collection to start so that there would be data available for analyses within the relatively short summer 6-week period.
3. *Early reminders of project presentations*. Early reminders of upcoming project presentations at the end of the summer would be helpful to suggest to teachers to be sure to take adequate pictures and documentation of the research process for sharing with others. Especially things that didn't work – much is learned for things that didn't work out as planned!
4. *Modifying research projects to be more hands-on*. Some of the research projects (especially noted was the battery project) had less hands-on and data collection aspects than others. Consider how those projects might be modified to permit more direct teacher hands-on engagement.
5. *Continuation for participation in the research projects.* Would like to see the subsequent fruits of the project they were working on – if next year teacher groups are to continue some of these projects, they would like to be invited back to any presentations about what the next groups are finding out so that they can see how the work is progressing from the efforts they did the summer before.

9. Conclusions

Program administrators are overall quite pleased that, through the first two years of implementation, the RET via RET program has more than adequately met preestablished goals. The results discussed above show that essentially all evaluative metrics, across a wide-range of programmatic features, were strongly positive. The program is specifically strong thus far in enhancement of teacher knowledgebase and comfort in engineering design thinking, effective at providing engaging while not overwhelming energy research involvement, and the LG&E industry tours in particular have been popular with each and every participant. Feedback resulting from participant focus groups has resulted in several program modifications that have further augmented the experience for future participants. At present, nearly all follow-up support and observation of project-developed and classroom-integrated curriculum has been satisfactory, especially pedagogy associated with engineering design thinking. In summary, through the first two years of existence, the RET via RET project has been deemed by program participants, partners, and administrators as very effective, diverse, and enjoyable at such a high level that project leaders are strongly considering applying for a renewal in hopes of sustaining the program several more years as a continuing benefit to the community.

References

[1] Carnegie Corporation. *The Opportunity Equation: Transforming Mathematics and Science Education for Citizenship and the Global Economy*. Carnegie Corporation of New York, 2009. Available at: https://www.carnegie.org/media/filer_public/80/c8/80c8a7bc-c7ab-4f49-847d- 1e2966f4dd97/ccny_report_2009_opportunityequation.pdf accessed September 2022.

[2] Carr RL, Bennett LD, IV, & Strobel J. "Engineering in the K-12 STEM Standards of the 50 U.S. States: An Analysis of Presence and Extent," *Journal of Engineering Education*, 101(3), 539-564, 2012. Available at: http://onlinelibrary.wiley.com/doi/10.1002/j.2168-9830.2012.tb00061.x/pdf accessed September 2022.

[3] Hanushek EA, Woessmann L, Jamison EA, & Jamison DT. "Education and Economic Growth," *Education Next*, 8(2), 62-70, 2008. Available at: http://educationnext.org/education-and-economic- growth/ accessed September 2022.

[4] Carlson L & Sullivan J. "Exploiting Design to Inspire Interest in Engineering across the K-16 Engineering Curriculum," *International Journal of Engineering Education*, 20(3), 372-380, 2004. Available at: http://citeseerx.ist.psu.edu/viewdoc/download;jsessionid=1215ADF3A81A46EE8947287A7D4FFAF8 ?doi=10.1.1.471.1634&rep=rep1&type=pdf accessed September 2022.

[5] Brophy S, Klein S, Portsmore M, & Rogers C. "Advancing Engineering Education in P-12 Classrooms," *Journal of Engineering Education*, 97(3), 369–387, 2008. Available at: http://www.ciese.org/publicity/publicity_2008/Advancing_Engineering_Education.pdf accessed September 2022.

[6] Mercer N, Dawes L, Wegerif R, & Sams C. "Reasoning as a Scientist: Ways of Helping Children to Use Language to Learn Science," *British Educational Research Journal*, 30(3), 359-377, 2004. Available at: http://onlinelibrary.wiley.com/doi/10.1080/01411920410001689689/abstract accessed September 2022.

[7] Anderson D, & Moeed A. "Working Alongside Scientists," *Science & Education*, 26(3-4), 271-298, 2017. Available at: https://link.springer.com/article/10.1007/s11191-017-9902-6 accessed September 2022.

[8] Westerlund JF, García DM, Koke JR, Taylor TA, & Mason DS. "Summer Scientific Research for Teachers: The Experience and its Effect," *Journal of Science Teacher Education*, 13(1), 63-83, 2002. Available at: http://www.tandfonline.com/doi/abs/10.1023/A%3A1015133926799?journalCode=uste20 accessed September 2022.

[9] McLaughlin CA, & MacFadden BJ. "At the Elbows of Scientists: Shaping Science Teachers' Conceptions and Enactment of Inquiry-Based Instruction," *Research in Science Education*, 44(6), 927–947, 2014. Available at:

https://repository.si.edu/bitstream/handle/10088/22715/stri_RISE_article.pdf?sequence=1&isAllowed =y accessed September 2022.

[10] Fayer S, Lacey A, & Watson, A. *STEM Occupations: Past, Present, and Future*. Report prepared by the U.S. Bureau of Labor Statistics, 2017. Available at: https://pdfs.semanticscholar.org/82c3/4b06c6aa1ac049349658ce9037e72fcf5b46.pdf accessed September 2022.

[11] Dushcl RA. "Chapter 11: Making the Nature of Science Explicit," *Improving Science Education: The Contribution of Research*. Millar R, Leach J, & Osborne J, Editors. Philadelphia: Open University Press, 2000.

[12] McNeill KL, & Berland L. "What Is (or Should Be) Scientific Evidence Use in K12 Classrooms?" *Journal of Research in Science Teaching*, 54(5), 672-689, 2017. Available at: http://onlinelibrary.wiley.com/doi/10.1002/tea.21381/abstract accessed September 2022.

[13] Yin RK. *Case Study Research: Design & Methods* (4th edition). Thousand Oaks, CA: Sage, 2009.

[14] Bussey LH, Sass H, & Bottoms G. "Findings from 2009-2010 Field Tests of an Induction Model for Alternatively Certified Career and Technical Education Teachers," Association for Career and Technical Education Research Conference, Las Vegas, NV, December 2, 2010. Available at: http://www.nrccte.org/sites/default/files/uploads/2010acter_bussey_findingsfieldtest_paper.pdf accessed September 2018

[15] Friedrichsen PM & Dana TM. "Using a Card-Sorting Task to Elicit and Clarify Science-Teaching Orientations," *Journal of Science Teacher Education*, 14(4), 291-309, 2003. Available at: https://www.jstor.org/stable/pdf/43156324.pdf accessed September 2018.

[16] Robinson, B., Thompson, A., Eisenmenger, G., Hieb, J., Lewis, J. E., & Ralston, P. (2015). Redesigning the First-Year Experience for Engineering Undergraduates. In *Proceedings of the 7th First Year Engineering Experience (FYEE) Conference*.

[17] Robinson, B. S., McNeil, J., Thompson, A., & Ralston, P. (2016, July). Continued Development and Implementation of a Two-Course Sequence Designed to Transform the First-Year Experience for Engineering Undergraduates. In *FYEE Annual Conference The Ohio State University Columbus, Ohio*.

[18] Robinson, B. S., & Hawkins, N., & Lewis, J. E., & Foreman, J. C. (2019, June), *Creation, Development, and Delivery of a New Interactive First-Year Introduction to Engineering Course* Paper presented at 2019 ASEE Annual Conference & Exposition, Tampa, Florida. https://peer.asee.org/32564

[19] Robinson BS, Lewis JE, Hawkins, NA, & Tinnell, TL. "Addressing First-Year Interest in Engineering via a Makerspace-Based Introduction to Engineering Course," ASEE 127th Annual Conference & Exposition, Virtual, June 21-25, 2020.

[20] Hawkins, NA, Robinson BS, & Lewis JE. "Employment of Active Learning Pedagogy Throughout a Makerspace-Based, First-Year Introduction to Engineering Course," ASEE 127th Annual Conference & Exposition, Virtual, June 21-25, 2020.

[21] Lewis JE, Robinson BS, & Hawkins, NA. "First-Year Engineering Student Perceptions in Programming Self-Efficacy and the Effectiveness of Associated Pedagogy Delivered via an Introductory, Two-Course Sequence in Engineering," ASEE 127th Annual Conference & Exposition, Virtual, June 21-25, 2020.

[22] Robinson, B., Lewis, J., & Hawkins, N., & Tretter, T., & Chan, F. B. (2022, August), *Converting a First-Year Engineering, Makerspace Course into COVID-Necessitated Fully-Online Synchronous Delivery and Related Student Perceptions* Paper presented at 2022 ASEE Annual Conference & Exposition, Minneapolis, MN. https://peer.asee.org/41024