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Work-in-Progress: The Design and Implementation of EFRI-Research Experience in Mentoring Catalyst Initiative

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Abstract

The National Science Foundation (NSF) Emerging Frontiers and Innovation (EFRI) Research Experience and Mentoring (REM) program nationally supports hands-on research and ongoing mentorship in STEM fields at various universities and colleges. The NSF EFRI-REM Mentoring Catalyst initiative was designed to build and train these robust, interactive research mentoring communities that are composed of faculty, postdoctoral associates and graduate student mentors, to broaden participation of underrepresented groups in STEM research who are funded through NSF EFRI-REM. This work-in-progress paper describes the first five years of this initiative, where interactive training programs were implemented from multiple frameworks of effective mentoring. Principal investigators, postdoctoral associates and graduate students are often expected to develop and establish mentoring plans without any formal training in how to be effective mentors. Since the start of this initiative, over 300 faculty, postdoctoral associates and graduate students have been trained on promising practices, strategies, and tools to enhance their research mentoring experiences. In addition to formal mentor training, opportunities to foster a community of practice with current mentors and past mentor training participants (sage mentors) were provided. During these interactions, promising mentoring practices were shared to benefit the mentors and the different mentoring populations that the EFRI-REMs serve. The community of practice connected a diverse group of institutions and faculty to help the EFRI-REM community in its goal of broadening participation across a range of STEM disciplines. Those institutions are then able to discuss, distill and disseminate best practices around the mentoring of participants through targeted mentored training beyond the EFRI-REM at their home institutions. Not only does the EFRI-REM Catalyst initiative focus on broadening participation via strategic training of research mentors, it also empowers mentees, including undergraduate and graduate students and postdoctoral associates, in their research experiences through an entering research undergraduate course and formal mentoring training workshops. Future expansion to other academic units (e.g., colleges, universities) builds on the research collaborations and the initiatives developed and presented in this work-in-progress paper. A long-term goal is to provide insights via collaborative meetings (e.g., webinars, presentations) for STEM and related faculty who are assembling an infrastructure (e.g., proposals for the ERFI-REM program) across a range of research structures. In summary, this work-in-progress paper provides a description of the design and implementation of this initiative, preliminary findings, expanding interactions to other NSF supported Engineering Research Centers, and the future directions of the EFRI-REM Mentoring Catalyst initiative.

Description of design and implementation of the Catalyst Initiative

This paper addresses the design and implementation of effective, intentional, and meaningful Research Experience and Mentoring programs as optional supplements within the EFRI division of NSF. To foster the optimization of implementation at scale, the Mentoring Catalyst team explored the history of the supplement, facilitators, and barriers to implementation. Data were collected from multiple complementary methods: listening circles, documents, training curricula, and mentor research implementation plans. These data lead to findings that provide a foundation for understanding the promising practices for replicating similar mentoring programs to change graduate education and postdoctoral research experiences in engineering

Background/overview

One of the most difficult jobs of a faculty member can be to positively mentor their graduate students and postdoctoral associates to be successful researchers and professionals. At times, faculty members may not be trained to be effective mentors and do not have a toolkit of mentoring skills to rely on when inevitable mentoring challenges occur. While there is significant evidence pointing to the value of promoting strong mentorship for research students, there are very few mentors who receive effective mentor training and mentors often rely solely on their past experiences and on observations of other mentors to build their own mentoring styles [1-2]. Therefore, it is vital to provide appropriate training for faculty mentors in effective mentoring so that they can aid their students to be as successful as possible during their formal studies and throughout their research careers. For graduate students and postdoctoral associates who are also learning to be effective researchers and professionals, the importance of proper mentoring is vital to their success and long-term career choices.

Studies of the impact of mentorship have shown that students who receive strong mentoring during research experiences have enhanced self-efficacy toward their research experiences [3-7]; greater persistence while engaged in research [8-10], increased research productivity [11-12], overall higher career satisfaction [13-14], and enhanced recruitment of underrepresented students [15]. However, as noted above, faculty members are often not well prepared to provide effective mentoring. Often first year faculty are mentoring for the first time and experimenting with mentoring styles that will work best for them. When a mentor chooses a mentoring style that does not fit their personality, it is often apparent to the student and may not appear to be genuine. First time mentors often will use mentoring techniques that were effective from their successes as researchers but may not fit their personality styles or the personality styles of their graduate students and postdoctoral associates. Alternatively, faculty who have had poor mentoring experiences will choose mentoring styles that are opposite to their experiences but still may not be appropriate for successful mentoring of graduate students and postdoctoral associates. Therefore, there is a great need to develop programs that provide effective training in mentorship.

The focus of this paper is to describe experiences from the development and implementation of the Emerging Frontiers and Innovation (EFRI) Research Experience Mentoring Program (EFRI-REM), supported by the National Science Foundation (NSF). The EFRI program from the Engineering Directorate at NSF has embraced the importance of mentoring and mentor training on research experiences of young and emerging researchers through its EFRI-REM program. The program provides supplements to selected NSF EFRI grantees to develop and implement a program that will train high school teachers, high school, undergraduate and graduate students, and/or faculty from select higher education institutions to be effective researchers. The EFRI-REM program is designed with a focus on sustained mentoring during and beyond the actual research experience. Furthermore, it is particularly interested in broadening participation (e.g., underrepresented minorities (URM), women and persons with disabilities) in Science, Technology, Engineering, and Mathematics (STEM) fields that are represented in the EFRI program. The program provides research opportunities for these unique demographics, the EFRI-REM PIs were originally asked to develop and implement a multi-level mentoring plan with limited training in how to be effective mentors. NSF believes that the EFRI-REM program has the potential to positively impact mentoring across engineering by providing real mentoring experiences for the next generation of faculty.

To address an identified gap in mentor training, the EFRI-REM Mentoring Catalyst initiative was established to 1) provide mentor training and 2) to build an EFRI-REM mentoring community composed of current and future science and engineering mentors. This initiative was developed with

NSF's perceived need in mind for specific training for EFRI mentors and mentees. The overarching mission of the EFRI-REM Mentoring Catalyst is to catalyze a core programmatic change that positively impacts the mentors and the student/teacher mentees in view of the importance of faculty mentoring. Sustained mentoring by graduate students and postdoctoral associates also guides the development of the initiative. The goal of this manuscript is to review experiences within the EFRI_REM Mentoring Catalyst Initiative and identify best practices in mentorship training and community building.

Goals and Components of the Mentoring Catalyst Initiative

The EFRI-REM Mentoring Catalyst initiative has three main goals, which are: 1) Provide meaningful and effective training of ERFI-REM faculty, graduate students, and post- doctoral mentors to impact the overall research experiences of their mentees; 2) Build a peer-mentoring community for EFRI-REM mentors to share ideas and provide support for real-time mentoring issues; 3) Strengthen mentoring relationships between faculty mentors and their graduate and postdoctoral mentees. There are four major activities associated with the EFRI-REM Mentoring Catalyst initiative focused on developing a community of ERFI REM Mentors and Program Directors with the express goal of enhancing the shared mentoring experience. These four activities include 1) mentor training programing; 2) development of communication tools; 3) establishment of a community of practice; and 4) identification of exemplary mentors from past programs to be named as "sage mentors'. These four activities are described in detail in the sections that follow.

Mentor Training Programs: A major component of the Mentoring Catalyst program is the training of EFRI researchers to be effective research mentors. To accomplish this goal the Catalyst team presented online and in-person mentor training seminars for EFRI-REM programs. The sections that follow describe the online trainings, three in-person meetings, and larger meetings that occurred in person and on-line at ERN meetings.

Online Trainings: For online training, the Mentoring Catalyst team used the validated and reliable Entering Mentoring Curriculum from the University of Wisconsin-Madison (REF). The curriculum was developed and evaluated through a series of grants from HHMI, NSF, and NIH. One of the Mentoring Catalyst PIs helped to develop the training and is a certified Master Facilitator of the Entering Mentoring Curriculum. To help build community and provide real time peer mentoring for EFRI Mentors, online mentor trainings were scheduled during REM program implementations. Mentors and facilitators gather weekly on Blackboard Collaborate to participate in the eight week mentor training curriculum. The weekly sessions served both as an opportunity to build mentoring skills, but also to provide real time support for mentoring challenges happening in REM programs. At the end of the eight weeks, the mentors developed and shared their own mentoring philosophies. The mentoring philosophies were collected for future dissemination via the EFRI-REM Catalyst website. Through the three summer mentor trainings the Mentoring Catalyst team trained over 30 EFRI Mentors from 17 different institutions.

In-person Mentoring Meetings: To further promote the importance and to catalyze institutional change the Catalyst team held three in person REM Mentoring Meetings. The Mentoring Meetings were designed to build on the momentum of the summer virtual mentor trainings and bring together EFRI-REM mentors to discuss current topics in mentoring and to provide support for mentors (faculty, and graduate students) implementing acquired mentoring skills. One of the

main goals of the mentoring meeting was to provide training for EFRI PIs and program directors to lead mentor training seminars at their home institutions and thereby catalyzing the impact of best practices throughout engineering departments nationally. Utilizing a Train the Trainer model the Mentor Catalyst team provided facilitation training for implementing Entering Mentoring. The facilitation training included opportunities for EFRI-REM programs to practice mentoring training while discussing core mentoring concepts. Mentoring Catalyst team members, who are also Entering Mentoring Certified Master Trainers, led the training efforts for the EFRI-REM PIs and graduate students. Another author delivered elements based in cross-cultural mentoring and critical aspects of broadening participation of different groups in STEM in the Mentoring Webinar Series. The brainstorming exercise yielded several items as elements to be considered for cross-cultural mentoring and issues of invisibility. Our final author presented core information on developing a working framework for the assessment and evaluation processes in a student focused research program.

Mentoring Summits at ERN Meetings: The Mentoring Catalyst team annually held a mentoring summit in February at the annual EFRI-REM PI meeting co-located with the ERN meeting. The annual meeting again brought together the EFRI-REM PIs and graduate student and postdoctoral associate mentors to discuss the importance of mentoring. At each annual EFRI-REM PI meeting the Catalyst team focused on a key aspect of mentoring and implementing EFRI-REM programs. Topics included best practices in REM implementation, sustainability of mentoring practices post REM support, and professional development as continued mentoring. During each focused session the Catalyst team lead in-depth discussions about best practices and idea sharing for how to collectively build on the experiences of the REM programs.

The in-person meetings and virtual trainings helped to build a REM community that collectively saw the value and importance of lifelong mentoring and commitment to continued study of the science of mentoring. Participants shared the understanding that effective mentoring takes practice and is ever evolving.

Communication tools: A key aspect of the EFRI-REM Mentoring Catalyst initiative is building tools to create a community to facilitate sharing of ideas and best practices in mentoring. To date, these tools have included the EFRI-REM Catalyst project website, webinar interface and the Moodle portal for project participants. Currently, a REM LinkedIn community has been established to create a virtual group to facilitate communication and connections between current and alumni REM participants and extend the value of the annual ERN conference for current participants. The intention of the group is to share thoughts, experiences, advice, resources, and contacts. Building this online community will be important for strengthening the REM community as the program matures, as members currently do not have any clear ways to find out about each other.

Community of practice: One of the major outcomes from the first Mentoring Catalyst project was the organic formation of a community of REM PIs and program directors. Prior to the EFRI-REM Mentoring Catalyst initiative, the programs PIs and Directors annually met only at the ERN meeting. Through the Mentoring Catalyst initiative, a REM "community of practice" was established, through the online mentor training and in-person REM mentoring meetings where the community had the opportunity to share ideas and strengthen their commitment to mentoring.

In communities of practice, groups of people gather and share a common interest and express concern for a set of specific challenges) [16]. According to Schön [17], learning different values and social norms and continuing in pursuit of maturing practice epistemologies and the prospect of developing their professional identities, participants can practice constants and norms associated

within their profession. This socialization is not an independent one-time event but rather a perpetual process that begins from the first group interaction that individual members embark on, whether in person or online, and continue from there [17]. According to Wenger, McDermott, & Snyder [18] a community of practice consists of three main components: the domain, the community, and the practice. Within the context of this work these components are applied to the concept of EFRI-REM Mentoring Catalyst 2.0.

The domain is a mutual area of interest, and membership implies a commitment to the domain [18]. EFRI-REM Mentoring fits within this definition, as it is a shared domain of interest; individuals seeking to gain knowledge about best practices based on past EFRI-REM experiences. Membership by these individuals certainly implies their commitment to this domain.

The community is built by members who participate in collaborative activities and discussions, assisting others and sharing ideas and knowledge [18]. Hence, EFRI-REM Catalyst mentors, former EFRI-REM PIs, and EFRI-REM research participants can be considered a community; the individuals gather together in various settings to assist each other and share best practices with one another. These members build relationships with one another and learn from each other solidifying that they are part of the community. Likewise, the EFRI-REM catalyst platform provides the appropriate environment to foster the community in communities of practice. The practice consists of practitioners who create a shared collection of resources [18]. The EFRI-REM mentors are the practitioners, interweaving their experiences, narratives, problem-solving skills, and tools into communities of practice. In communities of practice, members are EFRI-REM Catalyst mentors, former EFRI-REM PI, and EFRI-REM research participants that actively work together to overcome complex challenges, to enhance their learning potential and complete mentoring tasks in the field of engineering.

Sage mentors: A new addition to the Mentoring Catalyst program is the inclusion of "Sage Mentors" to provide peering mentoring for new REM programs. Sage Mentors are members of the REM community of practice who no longer have an active REM program but are exemplars for promoting effective mentoring and REM program implementation. Sage Mentors strengthen the REM COP by maintaining and building on the collective wisdom of the COP.

Program Evaluation

In order to understand the experiences and needs of EFRI-REM grantees, EFRI-REM awardees completed REM Mentoring Meeting surveys at the conclusion of the in-person REM Mentoring Meetings with both qualitative and quantitative assessment to provide feedback on the quality of the training. During in-person REM Mentoring Meetings the evaluator observed participants' behaviors and conducted semi-structured interviews to gain additional evaluation information not addressed by the surveys. At the individual level, the focus of this study was to explore the experiences, learning, behavior change, and strategies or practices most effective in operationalizing research mentoring in practice. At the institutional level, the focus of the study was to explore the potential implementation process, and potential strategies employed for fostering meaningful research mentoring experiences.

To answer guiding research questions, the following data collection methods were employed:

1. Interviews ("Roaming Reporter") with implementers and mentors during multiple gatherings;
2. Listening Circles (e.g., group interviews) with implementers and mentors;
3. Observations of in-person and online learning events;

4. Review of documents and artifacts (e.g., educational materials, implementation plans, project files, meeting minutes);
5. Multiple questionnaires to assess knowledge, satisfaction, change of behavioral practices and perceptions of implementers; and

Maintenance of a research journal with aligning field notes to keep a careful record of all research activities.

The data were analyzed using the constant comparative method [17-18] to identify emerging codes, categories, and themes across the entire data set. Research team members (Evaluator/PI, graduate research assistants, and volunteers) reviewed the data in a collaborative analysis process to identify salient themes. To ensure validity and reliability, the following steps were taken: prolonged and persistent engagement, multiple sources of data, multiple researchers, peer debriefing, thick description, reflexive researcher journals, and an audit trail.

Findings

The catalyst team spent a significant amount of time on the development and convening of the EFRI-REM constituents both in-person and online. One major outcome of the project has been the establishment of a REM community. The online meetings and in person meetings at ERN and during the summer event have built a community of mentoring practitioners who have relied on one another to help solve difficult mentoring situations.

For example, at the ERN meeting, each REM site was asked to do a short presentation on the challenges, successes, next steps and programmatic issues associated with the development, implementation and assessment of their programs. The items in Table 1 present answers to the questions: (1) What are some of the challenges and opportunities in your REM program? And (2) What are the successes that you have observed in your program? The results of this listening circle were shared with the NSF EFRI Program Director in an ERN session. This was followed by a robust discussion of recommendations to improve the program by the funding agency.

Table 1: Results of Listening Circle session with EFRI-REM PIs at ERN meeting

Challenges/Opportunities	Successes
● Mentoring regularity	● Mentees disagree with me
● Need specific guidance: "training content" & "tool sets"	● Mainstream publication
● Communicating with HS students/discovery	● Student recognition: International travel award
● Recruiting based on non-grade issues creates	● Full time graduate/research assistant in PI lab
● Maintaining strong mentor relationships post REM (especially if at other institutions). May include continuing mentoring relationship in school year	● Internal students continuing based on demonstrated progress
● Need earlier timeline for targeted recruiting	● Early engagement helps with capstone projects
● Inconsistent mentoring across participants	● Early training with mentors/mentees with enhanced training (EFRI-REM)
● Matching mentors/mentees	● Integrated learning into other 'REU' type programs

● Sustaining research after the summer; Transition to academic year from summer understanding expectations	● Evaluation of mentoring success
● Differing levels of maturity and aspiration (e.g., Ph.D.); Dealing with mentee's inexperience	● Generalized understanding of research process
● Achieving full two-way communication	● Prof. dev. activities well received
● Helping High School teachers plug into university networks	● Relationships continuing beyond projects for resource development (e.g., student equipment)
● Setting reasonable goals in a 2-month timeframe; Give opportunities with constraints	● Shine <u>light</u> on contributions to <u>really</u> advance the science; core to effect
● Keeping mentees engaged	● Build in funding for travel & mini workshops
	● Leveraging <u>branding</u>
	● All students applied to STEM program (**<u>real change</u>**)
	● Pre-research bootcamp
	● Weekly joint lab meetings (research + prof.dev)
	● FUN stuff > trips > team building > "hardcore/soft science" trips
	● Peer shadowing

Salient cross-cutting programmatic themes: Examining multiple sources of data yielded salient themes pertaining to challenges and successes that are useful in the implementation of EFRI-REM programming. For the purposes of this paper, several cross-cutting themes were identified as core to implementing EFRI-REM programs at both the individual/dyad and institutional levels.

Theme 1: Establishing effective recruitment efforts for equitable REM program access to underrepresented groups

REM implementers outreach to multiple groups and organizations to identify a wide array of potential program participants. Recognizing that programs are planned for varying groups, REM implementers expressed concerns regarding how to adapt their recruitment activities to ensure multiple streams of participants from varying educational backgrounds and settings have an opportunity to participate.

Theme 2: Engaging in cross-institutional collective gatherings fosters thoughtful dialogue and exchange among students, faculty, and program implementers

One unexpected but very important outcome of the online mentoring seminar and annual mentoring meeting is the interactions between faculty and graduate students and postdocs to discuss mentoring topics. Because participants are from different institutions, both faculty and students were able to discuss mentoring freely without repercussions of the inherent power dynamic of mentoring relationships. Both faculty and students were able to talk about mentoring from their perspectives which allowed faculty to gain a greater understanding of how students internalize mentoring from faculty and in turn students were better able to understand how faculty approach mentoring. This greater understanding will help both faculty and students build strong and more successful mentoring relationships.

Theme 3: Adapting mentor research content to align with institutional needs and context

While the Mentoring Catalyst team provided a cadre of mentor research resources, REM implementers expressed a need to adapt the content to the needs of their respective institutions. For example, some institutions selected dyad and small group approaches while others opted for distance options. Furthermore, given the limited timeframe, many REM implementers have to design and enact mentoring plans once awarded, setting reasonable goals and expectations is essential for adapting research mentoring content to meet specific institutional needs. REM implementers reported the need to initiate training early in the programmatic design process.

Conclusion

The EFRI-REM Mentoring catalyst team continues to run quarterly webinar activities and annual summits in person and online independent of the three activities that build on the content gleaned from sessions with the mentors over the past few years. Webinar and summit topics include: (i) Implementing customized smaller scale mentee training activities (e.g., adapting content to PI group/departmental/college), (ii) connecting to diverse populations (e.g., HBCU webinar), (iii) National Mentoring Month Town Hall meetings. The EFRI-REM Mentoring catalyst team and EFRI-REM program PIs meet annually as a group during the annual ERN meeting and hold additional mentoring in person or online summits in each summer. Additional offerings also include an in-person or online workshop to discuss and address mentoring issues that arise during the summer.

The primary goal of the EFRI-REM program is to provide meaningful and successful research experiences for undergraduate and graduate students and postdoctoral associates from underrepresented groups. NSF understands the need for intentional mentoring to encourage persistence of REM participants in future research careers. In order for the REM program to be successful, the NSF has identified a strong need for mentor training for faculty, postdoctoral associates and graduate students affiliated with large scale, multi-investigator and multi-institutional research endeavors. The team associated with the EFRI-REM Catalyst initiative has developed interactive programs that build on multiple frameworks of mentor training. The impact of this initiative has been expanded to include participants in the NSF supported Engineering Research Centers (ERCs). The EFRI-REM Catalyst initiative is positioned to impact engineering research by focusing on broadening participation via strategic training of both mentors (and mentees) in the research continuum.

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