

Engagement in Practices: Online Handbook for Engineering Research Center's Best Practices for Pathways and Mentoring

Dr. Hwangbo Bae, University of Michigan

Dr. Hwangbo Bae is a research specialist in the Department of Industrial and Operations Engineering at the University of Michigan. He works with Dr. Joi Mondisa, manages multiple research projects, and mentors graduate students. He has expertise in qualitative research design, engineering workforce development, retention and recruitment, and students' career pathways. He received a Ph.D. degree in civil and coastal engineering at the University of Florida in 2022. He received a Bachelor of Science and a Master of Science degrees in Civil and Environmental Engineering at Virginia Tech in 2018 and 2019, respectively.

Dr. Joi-Lynn Mondisa, University of Michigan

Joi Mondisa is an Associate Professor in the Industrial & Operations Engineering Department and Graduate Program Director of the Engineering Education Research Program at the University of Michigan. Her research focuses on mentoring practices, programs, and experiences as well as professional development in STEM. Prior to her graduate studies, Dr. Mondisa spent 10 years working as a professional in manufacturing, operations, technical sales, and publishing. During that time, she also taught engineering technology courses at Triton College in River Grove, Illinois, for seven years. She earned a B.S. in General Engineering from the University of Illinois at Urbana–Champaign, an M.B.A. from Governors State University, an M.S. in Industrial Engineering, and a Ph.D. in Engineering Education from Purdue University.

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The United States National Science Foundation (NSF) Engineering Research Centers (ERCs) play an important role in advancing interdisciplinary research and preparing the future engineering workforce. Through collaboration across multiple institutions and disciplines, ERC members work to address critical societal challenges while also providing professional development opportunities for students. At the same time, ERC leaders often face difficulties in building collaborative research environments, running effective mentoring programs, supporting clear student pathways, and securing the resources needed to sustain their work. These challenges are further complicated by NSF's funding period, which supports ERCs for a maximum of ten years and may limit opportunities to share barriers and lessons learned across centers.

To respond to these challenges, we created a Best Practices Online Module for Pathways and Mentoring that presents recommendations for mentoring, student professional development, and strategic knowledge dissemination. Leaders and faculty members can adapt the module's practical examples and guidance to their own centers. This paper demonstrates the module's purpose, details its design and refinement process, and underscores its primary content areas. We conclude by discussing how program leaders might use the module and ways it could be further developed to strengthen ERC practices.

Overall, this paper emphasizes the importance of sharing both challenges and opportunities related to student learning in ERCs. It also shows how the Best Practices Online Module for Pathways and Mentoring can support ERC sustainability while helping students' professional development.

Introduction

In the United States, Engineering Research Centers (ERCs) play a crucial role in advancing interdisciplinary research and developing tomorrow's workforce. Funded by the National Science Foundation (NSF), ERCs are designed to cultivate engineering talent across all career stages, create inclusive environments that draw on a wide range of perspectives and experiences to benefit all participants, and establish innovation ecosystems that are sustained beyond the centers' 10-year funding period [1].

At the heart of the center's success, trainees, such as graduate students and postdocs, collaborate closely with faculty members, driving research productivity and advancing the center's core objectives. To support student growth, ERCs provide robust mentoring and professional development opportunities, whose progress and impact are systematically measured, reported, and used for continuous improvement through annual evaluations as part of the center's performance [2].

However, many ERC directors and faculty members face practical challenges, such as creating professional development opportunities and developing training workshops for student trainees at multiple participating universities. While these opportunities are critical for trainees' professional growth, faculty members and directors may lack clear guidance and proven strategies, or best practices. Despite assuming these responsibilities, many leaders have limited access to the necessary tools and guidelines to provide effective support.

At minimum, ERC leaders may use the ERC Best Practices Manual NSF [3] as a resource to create trainee development programs and meet the center's overarching goals. For example, in this Best Practices Manual, the Diversity and Culture of Inclusion (DCI) chapter shares resources and general information about program design. The chapter offers an aspirational perspective on potential DCI program implementation.

Although useful, the ERC Best Practices Manual lacks clear examples and practices already implemented in a successful ERC. The abstract guideline invites ERC directors and faculty members to construct trainee programs from the ground up, requiring them to invest significant time and energy in developing resources, some of which may need to be sourced from external networks.

Drawing on the authors' professional experiences and leadership role within ERCs, this Engagement-in-Practices paper describes the processes and key strategic criteria to developing an online resource to address these critical challenges. Our best practices online module provides hands-on guidance for developing strategic dissemination plans, mentoring students, and formulating student trainees' career pathways programs. We focused on developing best practices that help ERCs adopt and support students from diverse backgrounds and maintain meaningful research connections.

Background & Rationale

To achieve their objectives and demonstrate measurable performance, ERCs must develop a strategic dissemination plan. This step is particularly crucial given the involvement of multiple universities and diverse fields of study in ERC projects [4], [5]. For ERC directors, key actions

include formulating a comprehensive dissemination strategy and assembling a dedicated team to implement it effectively. Emphasizing strategic dissemination meetings early on also fosters collaboration and teamwork, allowing team members to provide updates on active projects and collectively explore various methods for distributing research findings at local and national levels [6].

Furthermore, trainees' professional development should be a priority for ERCs to successfully operate. Among various professional development opportunities [7], [8], mentoring programs and relationships are particularly vital for student trainees, significantly impacting their performance [9]. Research from the National Academies of Sciences, Engineering, and Medicine (NASEM) highlights that structured mentoring significantly improves student retention, motivation, and career readiness in STEM disciplines [10], particularly for underrepresented groups in STEM [11-12].

Additionally, clearly defined student pathways programs, including structured research experiences and industry partnerships, facilitate smoother transitions into graduate studies or employment [12-14]. Despite strong evidence supporting these practices, ERC directors often face resource limitations and institutional constraints, restricting their consistent implementation of evidence-based interventions. Without clear guidelines or shared understanding of how to launch these initiatives and establish clear milestones, ERC leaders may struggle to organize effective programs. To address these challenges, this Engagement-in-Practices paper provides actionable strategies and real-world, contextual examples for ERC leaders and faculty to implement within their centers. Additionally, the paper offers implications for educational program managers interested in adopting similar approaches to strengthen students' learning environments.

Module Development

The module was developed through close collaboration among team members, including the authors, who leveraged their experiences, available resources, and empirical research. However, because the authors joined the ERC in its sixth operational year, certain historical information about earlier activities was not immediately accessible and required intentional effort to obtain. To address these gaps, the authors consulted two education and outreach coordinators who have served the ERC since its inception to gather institutional knowledge. In addition, annual reports submitted to NSF were reviewed to obtain detailed descriptions of prior activities. Through this combined approach, the authors developed a comprehensive understanding of earlier initiatives, identified examples of best practices, and ensured the integration of diverse perspectives.

After iterative discussions, the authors clearly defined the scope of the module. To support the development of the online module, an instructional designer from the affiliated university was subsequently contacted and hired. During the initial meeting with the instructional designer, the team discussed and identified key strategic criteria essential for effective module development, as summarized in Table 1. This collaborative discussion helped align the instructional design with the ERC's educational objectives and user needs.

Table 1. Key strategic criteria for developing the Best Practices Online Module

Criteria	Details
Target Users	• ERC Directors • Faculty Members • Staff Members, such as education and outreach coordinators
Goals	• Showcase best practices from Pathways and Mentoring teams • Demonstrate how to operationalize these activities • Supplement Chapter 7 of the NSF's ERC Best Practices Manual NSF, [3]
Existing Materials	• Scholarly publications by the Pathways and Mentoring team • Mentoring workshop presentation slides and handouts • Past activities from the Annual reports
Needed Materials	• Stakeholder informal meetings • More details on past and ongoing activities • Photos and resource links
Approaches to obtaining the Materials	• Schedule informal meetings with stakeholders • Review annual reports
Key Elements for Developing an Online Module	• Define the module scope and responsibilities • Hire an Instructional Design Manager ◦ Define scope, cost, and hiring period • Set clear timelines and check-in points • Add, refine, and revise materials and visuals through iterative process • Review and proofread all content before launch
Platform	Canvas by Instructure, Inc.: • Institutionally approved • Fully manageable by faculty • No cost • Accessible to users • Tracks user access via Qualtrics
Monitoring Tool	Qualtrics Invitation Survey: → Track user types and purposes Qualtrics Feedback Survey: → Improve the user experience and the quality of contents

Results

The final module, as shown in Figure 1, includes six core content areas: (1) Onboarding Materials, (2) Best Practices for Pathways and Mentoring Directors, (3) Training and Mentoring Resources, (4) Approaches and Methods for Education and Outreach Program Coordinators, (5) Innovation and Translational Practices, and (6) Publications.

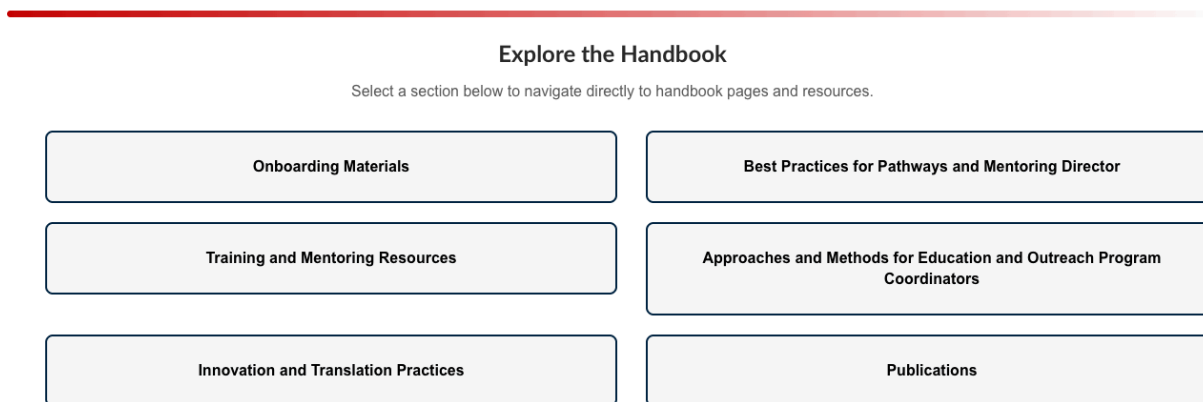


Fig. 1 Homepage of the Best Practices for ERC's Pathways and Mentoring Team Online Module

Within Onboarding Materials (1), the module provides structured resources to support the integration of new members, including example onboarding documents and orientation strategies. This resource is designed for new members to understand the overarching goal of the center and points of contact. Best Practices for Pathways and Mentoring Directors (2) highlight effective leadership approaches, including strategic planning and meeting guidelines that support coordination, communication, and dissemination efforts. The Training and Mentoring Resources area (3) focuses on strengthening mentoring foundations by fostering effective mentoring relationships, cultivating inclusive mentoring environments, and implementing tailored practices that support diverse student populations through workshops designed for both faculty mentors and trainees. Specifically, this content area offers mentoring workshops tailored separately for faculty and student trainees, ensuring each group takes on appropriate roles and shares responsibilities for lab management and personal development. In Approaches and Methods for Education and Outreach Program Coordinators (4), the module outlines practical strategies for designing and implementing education and outreach activities, including examples of program structures and engagement methods. Innovation and Translational Practices (5) includes example activities and workshops that train mentors to help trainees translate research into practice through collaboration across academic and industry contexts. For example, we included a list of activities and training programs, such as the Engineering Engagement Kit (EEK!) [15] to help ERC students move effectively from research into professional careers. Finally, the Publications area (6) provides guidance on disseminating research outcomes to both academic and broader audiences, including examples of communication strategies, dissemination planning, and documentation of program impacts.

Implications and Future Work

We believe that this module has effectively addressed the need for best practices in managing pathways and mentoring programs at ERCs. The content is designed to enhance clarity in mentoring expectations, improve student engagement, and support smoother onboarding experiences for new directors, faculty members, and staff. Through engaging with this module, faculty members can develop greater confidence in their mentoring abilities and gain clearer frameworks for structuring meaningful student experiences. Rather than creating activities from the ground up, ERC leaders and faculty mentors can adapt the materials and content shared here

to fit their own contexts and learning environments. This approach saves valuable time and energy, allowing them to focus on implementing and refining activities that best suit their ERC's unique needs. Interested readers are invited to complete the brief survey and explore the module materials, using the reference provided here [16].

Additionally, this paper offers valuable insights for engineering educators across diverse programs by presenting approaches to developing educational modules. It provides practical strategies to maximize institutional resources and outlines a step-by-step roadmap for educational program managers, from identifying initial needs to final implementation. By highlighting this structured yet adaptable approach, the paper helps educators create effective, user-friendly online learning content tailored to their institutional goals.

For our future work, we would like to understand user experiences and continually enhance the module's content quality. To achieve this goal, we included a voluntary feedback link within the platform. Users are encouraged to share their experiences, suggestions, and concerns, allowing us to identify specific areas needing refinement. We believe that constructive feedback would ensure the module remains relevant, effective, and responsive to user needs.

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