Creating a Sustainable Research Group Supporting the Professional Development of Engineering Education Graduate Students and Postdoctoral Researchers

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***Abstract*—This Innovative Practice Paper describes the process and strategies employed by a discipline-based engineering education researcher that led to creating a sustainable research group supporting the continuing professional development of graduate students and postdoctoral researchers. One challenge faced by early-career faculty situated within research-intensive universities is developing and sustaining a robust research enterprise that includes recruiting, funding, mentoring, and graduating students and postdoctoral researchers. For faculty involved in a new and/or developing research area (e.g., engineering education), the challenge increases exponentially with limited research support and ambiguous metrics of success. The paper uses a model of workforce sustainability as a lens through which the engineering education community can view approaches to developing graduate students and postdoctoral researchers. The model of workforce sustainability includes eight attributes to define a workforce and its sustainability: nurturing, diversity, equity, health and well-being, connectivity, value, community, and maturity. In this paper, it is shown how the model guided the creation of a five-step process (with associated practices) to support the development of a sustainable research group: (1) Defining Goals and Values: Goal setting and reflection, (2) Onboarding Personnel: Retreat and Orientation, (3) Labeling Experience: Scholar Development and Faculty Practicum, (4) Uncovering Norms: Director Accessibility and Facilitation of Access, and (5) Informing Progress: Performance Evaluation. The primary goal of this innovative practice paper is to present a description and reflection that explain how the process and strategies have been used to create a sustainable research group in an emerging field like engineering education. Since the model provides an overview of key components of a process, this paper contributes an understanding of how to apply the model to maintain consistency and a rationale for practices, and how to attach individual practices to achieve stated outcomes or adapt the model to fit individual environment/context and desired outcomes.**

Keywords—faculty development, graduate education, postdoctoral studies, mentoring

I. Introduction

Graduate school is a critical time in any scholar's career as professional identity is developed, social norms of the profession are learned, and foundational knowledge mastered [1-4]. Attrition rates of doctoral students across fields of study are high [5,6] and this trend has persisted across time and geography [7]. Researchers have suggested a number of factors connected to graduate student attrition, including quality of doctoral supervision, departmental culture, financial constraints, mental health, and a difficult and confusing dissertation process [6,8-10], suggesting the graduate school experience needs to be examined and changed to better support emerging scholars. Additionally, as many fields of study try to diversify their workforce, special attention is being paid to best practices for supporting underrepresented students [11-14].

In engineering, for those who completed doctoral work in 2020, 35% accepted a position as a postdoctoral researcher after graduation [15]. In research groups that include postdoctoral researchers, questions arise about how to best support postdoctoral researchers in their continued journey towards faculty jobs and other professional employment. Postdoctoral researchers are no longer graduate students and therefore have different needs and bring more fully developed skills and expertise to a research group. However, postdoctoral researchers are also not yet full faculty members, creating a unique situation where learning and mentoring are still critical but the issues of power and hierarchy can be unclear and difficult to navigate. Surprisingly, however, there is little research on the development and support of postdoctoral researchers, with scarce information on the role of postdoctoral researchers in research groups.

Much of the burden of providing a supportive and effective research group experience for both graduate students and postdoctoral researchers falls to faculty, who are largely responsible for structuring and providing graduate coursework, lab experiences, and mentoring. This can be challenging as faculty balance a number of responsibilities, including research (with its many steps from securing funding, conducting studies, and presenting findings), undergraduate and graduate teaching, and professional service. Early career faculty may struggle with providing effective graduate student training as this topic is often not explicitly covered in their own doctoral training and the doctoral supervision process is often described as being shrouded in secrecy [10,16-19].

The issue of developing and supporting an effective research group that meets the needs of students, postdoctoral researchers, and faculty is complicated in emerging fields like engineering education, where practices and trends may be under-researched and not yet well understood. Given the interdisciplinarity of engineering education, faculty can draw upon research group best practices from engineering and education, but successfully melding these two areas may take time as this process involves lots of trial and error and often lacks an evaluative component to measure success. In this innovative practice paper, I share not only practices and strategies I use in my civil engineering education research group, but provide a comprehensive model that incorporates these practices and strategies while showing the rationale behind them. Sharing the larger system surrounding research group practices and strategies facilitates adaptation and use of practices and strategies by answering not only the question of *what* to do, but *how* and *why* to do it.

II. The Workforce Sustainability Model

The development and implementation process of my research group is based on a model of workforce sustainability [20]. This model was developed in the context of the construction industry, but is applicable to any workforce. Engineering education researchers have described a "community of practice" in engineering education [4,21-22], where graduate students and post-doctoral researchers learn about their profession and develop their professional identity through interactions with faculty, program staff and administration, and other people who they encounter in their graduate studies. I view this community of practice as a workforce where future engineering educators (current graduate students and postdoctoral researchers) are developed and a context where the workforce sustainability model applies.

The workforce sustainability model is the result of a mixed-methods study involving a literature review, interviews, and expert survey [20]. The model's purpose is to help advance workforce sustainability and includes an assessment tool to gauge the level of sustainability in a workforce. The three levels of the model are attributes, indicators, and metrics—all of which can be applied in a practical setting. While the indicators and metrics are effective tools for evaluating a research group and represent an area for future study and discussion, the focus of this Innovative Practice Paper is on the attributes, which are defined by [20] as the foundational characteristics and qualities of a workforce. The eight attributes are listed and defined in Table I.

I used the eight attributes of the workforce sustainability model and their accompanying definitions [20] to design a plan to develop, implement, and support my research group. I mapped the attributes onto the three phases of graduate study proposed by [1]: admission, integration, and candidacy. As my research group includes both graduate students and post-doctoral researchers, I needed a research group process that addressed the needs of both these groups. While I have found some strategies and practices are applicable when working with either group, there are also differences that need to be acknowledged and addressed. I was mindful of the needs of postdoctoral researchers as I developed my research group process and made sure to reflect on how the application of the attributes of the workforce sustainability model would be similar and different for postdoctoral researchers when compared to graduate students. I initially created a research group process prior to having significant numbers of graduate students and postdoctoral researchers, but as the plan was put into practice, I revised the plan and process based on feedback, observation, reflection, and going back to the workforce sustainability model as needed. In the next section, I share an overview of my civil engineering education research group development and implementation process.

TABLE I. Workforce sustainability model

Attribute	Definition
Nurturing	Feeling of support and encouragement and receiving training
Diversity	Diversity and inclusion related to personal characteristics
Equity	Fair treatment and compensation
Health and Well-being	Physical, social, and mental safety and contentment
Connectivity	Connection to, and communication between, peers and management
Value	Feeling of value, respect, and recognition for contribution to the organization
Community	Camaraderie and cohesion in the organization and workforce
Maturity	Opportunity to gain responsibility, leadership, and competence

III. Process for Creating and Sustaining an Effective Research Group

Over my nearly twenty years in academia, I have formed and led a civil engineering education research group at two state universities. Although the focus of these two research groups has been civil engineering education, the home departments have been civil engineering and management and civil and coastal engineering. These research groups have been made up of a range of two to fifteen people and have included undergraduate students, graduate students, and postdoctoral researchers. During that time, I have created and refined a five-step process, informed most recently by the workforce sustainability model, that includes strategies, practices, and evaluation. These five steps are designed to occur over an academic year. The five steps are presented in Table II, accompanied by the main practices associated with each step. In the following sections, I describe each step.

A. Step 1: Defining goals and values

Prior to the start of any academic year (frequently in the summer months prior to the start of the academic year), I identify objectives linked to the overarching goals to guide my research group based on a combination of what I need from my research group over the academic year and what is needed from me and others to best support the professional development of the members of the research group. The overarching goals of my research group are to recruit motivated and talented graduate students who aspire to create knowledge related to workforce development in civil engineering, disseminate use-inspired

basic research, and obtain funding to support the research group. For example, three recent objectives for my research group were:

- Develop and implement a recruitment (i.e., advertisement and selection) strategy to hire a graduate student preferably with research experience in human-robot interactions
- Assess the effectiveness of the peer-to-peer mentoring that occurred in the previous semester and revise the interactions to improve effectiveness and meet the objectives of the upcoming semester
- Using the weekly, one-hour group meetings over a semester to provide drafts and gain feedback, improve the findings, implications, and graphics to be included in a developing journal manuscript on recruiting and retaining employees

TABLE II. STEPS AND PRACTICES TO DEVELOP AND IMPLEMENT AN ENGINEERING EDUCATION RESEARCH GROUP

Step	**Associated Practices**
Defining goals and values	Goal-setting and reflection
Onboarding personnel	Retreat and orientation
Labeling experience	Scholar development and faculty practicum
Uncovering norms	Director accessibility and facilitation of "access"
Informing progress	Performance evaluation

After drafting these objectives, I communicate each to the research group and connect my activities and that of my research group members to each objective. Therefore, we each understand how our actions over a semester will help achieve one or more objectives.

During this step, I also spend significant time reflecting on the values I want the research group to embody. While these values certainly stem from personal values, I also draw upon outside sources, such as research articles, newsletters, blogs, observation of other research groups, and insights from colleagues. For example, since developing the workforce sustainability model and assessment tool [20], I have used the eight attributes of that specific model to guide this step of reflection. This in-depth and ongoing reflection has led to the creation of a list of desired qualities and characteristics for my research group:

- We will produce high quality work recognized and rewarded by scholars in our community and constituency we seek to influence.
- We will be the research group that high quality students seeking a PhD in civil engineering will desire to join.
- We will encourage one another and help each other meet goals and succeed.
- Graduates of our research group will be influencers in the public and private sectors and work in industry, government, think tanks, academia, and their own companies.
- Each year's goals and values are written down to be shared with new and returning members of the research group. The goals and values guide the rest of the steps described below.

B. Step 2: Onboarding personnel

Following goal and value development, at the start of the fall semester, I launch the next step of onboarding. This step involves welcoming new members of the group and welcoming back returning members. This step provides a systematic way of sharing the research group goals and values so there is no confusion about what needs to be done and what expectations are. The key practices of this step are a research group retreat and orientation. The process I use for the group retreat is described in [23] and is informed by my shared leadership style. The process for creating and leading change was anchored in John P. Kotter's eight steps. These steps are summarized from [24] and shown in Table III.

TABLE III. LEADING CHANGE PROCESS

Step	**Definition**
1. Establishing a sense of urgency	Understand the market and identify opportunities
2. Creating the guiding coalition	Assemble the team to lead
3. Developing a vision and strategy	Create the vision and step to attain it
4. Communicating the change vision	Articulate the idea and have the coalition model it
5. Empowering broad-based action	Remove the barriers to change by changing the system
6. Generating short-term wins"	Plan for and recognize improvements
7. Consolidating gains and producing more change"	Develop people who support the vision
8. Anchoring new approaches in the culture	Connect individual behavior and organizational achievement

There were four primary objectives for the retreat, which were motivated by various components of the change process and workforce sustainability model, as shown in Table IV.

These objectives were designed to leverage the theoretical frameworks while also addressing commonly cited challenges in graduate education.

Regardless of how the information is presented and exchanged (whether a group retreat at a location outside the university or a conventional orientation in the research group meeting space on campus), onboarding involves not only

sharing the research group goals and values but also gaining insights into each member's goals and devising an initial plan to achieve the goals for their time in the research group. At this stage, I also introduce them to my approach to providing training and professional development. As a part of my effort to create a multi-tiered mentoring experience, empower students, and promote confidence and connection, returning members of the research group are invited to help onboard new members.

TABLE IV. RETREAT OBJECTIVES

Objective	Organizational Change	Workforce Sustainability
Build community	Step 2: create guiding coalition	Community, connectivity
Develop individual strategic plans	Step 3: develop a vision and strategy Step 4: communicate the change vision	Maturity
Introduce basic research skills	Step 5: empower broad-based action Step 6: generate short-tern wins	Nurturing
Communicate group norms and expectations	Step 8: anchor new approaches in the culture	Value, connectivity

C. Step 3: Labeling experience

After the onboarding step, the research group digs into the real work of research and professional development as each group member defines and executes their needed experience. I am careful in how I describe or label this experience since labels have power. Also, the labels "graduate school" and "postdoctoral training" are vague and do not convey useful and relevant information to graduate students and postdoctoral fellows about the experience. For graduate students, I explicitly label this stage as "scholar development" as they learn the ins and outs of the research process and the associated skills pertaining to a range of research methodologies and methods. The focus is also on helping them develop their own identity as a researcher and may involve an introduction to management as they interact with undergraduate students and other graduate students. As an aside, I believe in preparing graduate students and postdoctoral researchers for the career they desire and believe my previous experiences in industry, as an entrepreneur, at a teaching-intensive institution historically Black university, and at predominately White institutions, I can prepare research group members for a range of careers. To date, I have yet to receive a research group member desiring a non-academic career but I welcome the opportunity to adapt my strategies to meet the needs of other careers desired by my students.

At this step of the research group process, I intentionally label the postdoctoral researcher experience as a "faculty practicum", with the goal of supporting their autonomy as a researcher and preparing for their career as a faculty member. I first labeled the experience as a faculty practicum to emphasize that the practice of being a researcher will be centered in the experience and shift the focus to inviting their knowledge to the process. The practicum includes goal setting three times per year, weekly meetings with me to gain support, quarterly conferences where any topic could be raised for us to discuss, and periodic faculty activity reports.

D. Step 4: Uncovering norms

No matter the amount of training one undertakes in preparation for a faculty career, there is still much to learn on the job, including the many unwritten norms of faculty life. The uncovering of norms is a critical step of a process I call "going from novice to expert". This step, which involves helping graduate students and postdoctoral researchers uncover the hidden yet omnipresent norms of their chosen careers, occurs concurrently with the experiences of Step 3. Step 4 frequently consists of continual observation, as norms are most easily learned and understood by observing others in action. I facilitate this observation by making sure students and researchers in my research group have a reasonable amount of access to me so they can observe my role as a faculty member and leader of a research group. This access includes providing opportunities to observe my teaching, sit in administrative meetings when appropriate, attend professional conferences, and participate in all the stages of the grant-seeking and grant proposal writing process. Additionally, when meeting with students and postdoctoral researchers, I make an effort to "think out loud" and voice thoughts that might otherwise stay internal. For example, in discussions with students, I might think out loud about funding and budget constraints to increase awareness of how research group leaders carry responsibility for the livelihoods of the research group members.

In addition to observation, another effective practice to uncover hidden norms is through posing questions and collecting answers from professionals currently working in the field of study. As a research group leader, I try to support this practice by providing opportunities for research group members to interact with faculty and researchers from within and outside of our home university. These opportunities may involve inviting speakers to research group meetings, alerting research group members to events (often offered through our department, university, or professional conferences) where faculty members will be accessible, and arranging site visits to other departments and universities. A critical part of these interaction and observation practices to identify and understand norms is personal reflection that includes checking assumptions, thinking of implications, and reflecting on any ethical and practical issues associated with the identified norms. In research group meetings and one-on-one meetings, we explicitly discuss professional norms we expect and have seen. By implementing and understanding these processes, I believe I help my students develop the ability to uncover norms occurring outside of our research group.

E. Step 5: Informing progress

Due to the ubiquitous role that performance metrics play in the academic world, it is useful for graduate students and postdoctoral researchers to gain an understanding of how such metrics work, how to develop and use metrics to inform their own progress, and how to evaluate the performance of others. In this step, which focuses on informing progress, I use performance evaluations to teach graduate students and postdoctoral researchers about expectations associated with

performance metrics that they are likely to encounter in an academic career, as well as benefits derived from developing and using personal performance metrics. For me informing progress is every bit as important as setting expectations. As discussed in Step 2, during the onboarding process, I work with research group members to develop semester and annual plans, which include both expectations and performance metrics. I work with each member to align their personal performance expectations to the broader objectives of the research group so everyone understands how they are contributing to the research group's success. As part of the development of these plans, we develop specific metrics to measure progress towards goals, which are translated into semester objectives and activities for the student. Because my university is on a semester system and I see the year as essentially three semesters, the process of setting objectives and evaluating progress occurs three times a year. For graduate students, the metrics are often tied to graduate program milestones as well as deliverables associated with current projects of the research group.

For the postdoctoral researchers, I have adapted my department's faculty activity report to develop their activity report. As I introduce the format, I describe what activities go in each section. I also recount my reaction the first time I completed one of these reports: I was panicked by the many places where I had no activity to report and asked my chair, "Am I expected to have content/activities in each of these sections?" It was after my chair's affirmative response that I understood I needed an ongoing, systematic process to have the "essential" sections incrementally filled to achieve the performance needed to earn promotions. My advice now to my research group is aligned with my realization all those years ago: Structure your semester activities such that you are able to add new entries to sections contained in your performance evaluation, in this case, the activity report.

As a final practice for this step of informing progress, I ask my graduate students and postdoctoral researchers to go a step beyond evaluating their own performance by also becoming intimately involved in evaluating the performance of other research groups members. For postdoctoral researchers, I have them mentor and then evaluate the performance of graduate students. Likewise, graduate students mentor undergraduate researchers and evaluate their performance. In this way, the postdoctoral fellows and graduate students gain experience in guiding and evaluating the performance of others. It is during this step and as part of these planned interactions that we celebrate progress. We celebrate cultural events, academic milestones (e.g., successfully defending a dissertation proposal, getting a journal article accepted for publication), and the completion of each semester. This practice is aligned with my belief that all researchers have to take moments to pause, reflect, and honor progress made and wisdom earned.

IV. Future Work

At my current stage in my career and work with research groups, I see several next steps in the development of a model for creating a sustainable research group that meets the needs of both the leader and other research group members. First, while collecting metrics and data has been a part of the process, this has been done very generally to gauge success. The data has not been compiled in a systematic way that allows for a broad analysis of trends, themes, and patterns. A logical next step is to conduct a formal evaluation of my research group's development to clarify what is working and what needs improvement. Such an evaluation could be conducted by an outside, third party and done in consultation with myself and my research group to ensure the metrics used are related to our group values (e.g., group sustainability, productivity, professional identity development, and inclusiveness) and that our work and process aligns with the models and theories we have prioritized.

The findings from a formal evaluation could serve as the foundation for developing an in-depth case study of the development of my research group. Eventually, if other research group leaders adapt the developed model, a cross-case analysis could be conducted. In an emerging field such as engineering education, such research on foundational yet everyday faculty practices could be beneficial to both engineering educators and the broader field of engineering.

V. Concluding Remarks

For over twenty years, I have been developing and refining this five-step process to create a sustainable engineering education research group. With these steps and practices, I have been able to manage my own progress toward research goals from year to year and align the actions of my research lab with those goals–all while helping group members gain professional competencies (e.g. writing, mentoring, presenting) that help develop a professional identity and accrue academic capital (e.g., publications, funded proposals) that sustain a research group. While I share and emphasize my research goals, flexibility is invited through lab members articulating their own goals and receiving my support to achieve these goals.

In recent years, the key to successfully managing a sustainable research group has been the use of the workforce sustainability model to guide processes, practices, and goal-setting. Further, I have distilled and translated my deep knowledge of project management and leadership theory to my practices in academia. By explaining how I used the workforce sustainability model and other internalized theory to shape my own model of research group development (which includes steps and practices), I seek to share my practice such that other faculty can adapt these approaches for use in their own labs.

Too frequently, early-career faculty become overwhelmed and frustrated by the career outcomes required over a particular span of time to achieve promotion and tenure, and lack the knowledge of a set of actions that might help them achieve these outcomes. There is so much to understand with little to no time in which to understand it. As a result, early-career faculty resort to simply acting without a model to guide their actions. While research group development is only one area of focus for early-career faculty, it is an important one as having a functional, productive, and sustainable research group can facilitate so many other areas of concern for early-career faculty (e.g., producing published work, securing grant funding, mentoring large numbers of students). I am committed to inspiring faculty to sustain an award-winning, thriving, and inclusive research group that results in scholars who will do the same. For me, that is the very definition of sustainability.

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