Development of STEM professionals when integrating education research and physics public engagement into their careers

by

Shams El-Adawy

B.A., American University, 2018

M.S., DePaul University, 2020

AN ABSTRACT OF A DISSERTATION

submitted in partial fulfillment of the
requirements for the degree

DOCTOR OF PHILOSOPHY

Department of Physics
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Abstract

To broaden participation in STEM (Science, Technology, Engineering, and Mathematics) education and continue building research capacity, this dissertation focuses on STEM professionals: those who take up education research later in their career and those who facilitate engagement in physics learning outside the formal classroom. Using agency, identity and motivation frameworks combined with qualitative research methodologies, we report on three projects that investigate how scientists integrate new research areas in their careers and engage with the public in order to gain a deeper understanding of their professional development needs.

First, through a multiple case study analysis of three participants in a professional development program, we use Bandura's theoretical framework on agency to investigate how program activities affect emerging STEM education researchers' agency. Our analysis illustrates a mechanism by which professional development opportunities worked in favor of increasing self-efficacy and echoed more broadly into agency. Our study highlights the importance of agency when creating professional development activities to increase and sustain engagement in discipline-based education research (DBER) in different institutional contexts.

Second, we use phenomenography grounded in Holland's figured worlds to identify the spectrum of ways emerging STEM education researchers identify or imagine themselves in DBER. We characterize three ways they conceptualize education research: to improve teaching, to join a new field of research or to negotiate their position and identity in DBER vis-à-vis their home discipline. The nuanced experiences of these emerging STEM education researchers bring to the surface the challenges and opportunities of emerging STEM education researchers. Their experiences illustrate the need for a variety of professional development support including but not limited to nuanced and explicit discussions of the

norms and culture of DBER within disciplinary science departments and discussions about DBER across STEM disciplines.

Third, we use personas methodology and Ryan and Deci's self-determination theory to articulate the motivation, challenges, and needs in public engagement of physicists with a range of different experiences. We discuss our personas refinement process, our set of personas and implications for the development of user-centered resources for the informal physics community. Our personas consist of the physicist who engages in informal physics for self-reflection, the physicist who wants to spark interest and understanding of physics and the physicist who wants to provide diverse role models to younger students and inspire them to pursue STEM careers. Needs covered a range of resources including science communication training, community building among informal physics practitioners and mechanisms to recognize, elevate and value informal physics. Using personas not only expands our understanding of motivations and needs of practitioners in physics public engagement, it brings user-centered design methodology to a new topical area of physics education research.

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Major Professor
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Dedication

To my parents and grandparents.

Chapter 1

Introduction

In support of current trends to broaden participation in STEM (Science, Technology, Engineering and Mathematics) by building STEM education and research capacity[1], this dissertation studies STEM professionals: those who take up education research later in their career, those looking to use education research to strengthen their classroom presence and those who facilitate engagement in physics learning outside the formal classroom. We examine how and why they navigate and conceptualize integrating new research areas and their experiences integrating informal physics in their careers. We investigate their agency development, perceptions, motivations, challenges, opportunities and needs as they pursue their STEM careers.

1.1 Motivation for Study

Building capacity and expertise in discipline-based education research (DBER) aligns with ongoing trends to improve STEM education to meet the current and future needs of the workforce. In the last decade, DBER has been promoted as an area to invest in to guide STEM education reform and changes as the higher education landscape and population evolve[1]. The emergence and proliferation of STEM education centers and centers for teaching and learning across universities are driven by the idea that becoming more scholarly about teaching will lead to the use of more research-based teaching practices, which will improve student learning outcomes[2]. The literature has studied STEM faculty who engage in education research when they are specifically trained in that research area[3]. However, the literature has not explored STEM DBER faculty who do education research with only discipline-specific training. Only recent research highlights some of the challenges emerging STEM DBER faculty face, while simultaneously recognizing the support these emerging professionals need[4]. This study fills the gap by getting a deeper understanding of emerging STEM education faculty's transition to DBER in order to provide insight into the type of mechanisms needed to best support them. Providing support to emerging STEM education researchers during their transition into a field of research that is new to them can help foster the development of high-quality DBER research and align with societal goals around STEM education. Therefore, the first part of this study focuses on the professional development of emerging STEM education researchers: STEM faculty who get started in discipline-based education research at different stages of their faculty careers.

Improving STEM education not only plays a role in preparing the STEM workforce, but it also plays a consequential role in society's relation and perception of science and in creating a science-literate society. Although most research focuses on improving STEM education focuses on improving learning in formal spaces, it is not the only space in which engagement with STEM happens. An increasingly growing body of literature has focused on informal spaces. Learning that happens in outreach and public engagement events is of interest to researchers who view it as a critical place for people from various backgrounds and knowledge areas to engage voluntarily in a learning space with science[5]. Researchers have shown the valuable role physics informal spaces play for its audiences, especially for underrepresented populations in STEM in increasing their sense of belonging in the field[6]. Although participants of informal physics activities have been studied, less research has focused on the motivations and needs of physicists who facilitate informal physics activities, events, and programs. The second part of this study aims to fill this gap in the literature by exploring physicists' experiences with facilitating informal physics activities in order to design resources and professional development initiatives to best support their needs.

1.1.1 Research Questions

In support of these broader issues in building STEM education and research capacity, the research purpose of this study is to understand the ways in which the STEM community can best support the professional development of STEM professionals who integrate education research or public engagement into their professional endeavors. In particular, we address the following research questions:

Research Question 1 (RQ1): How do emerging STEM education faculty gain agency during the process of engaging in discipline-based education research?

Research Question 2 (RQ2): How do emerging STEM education researchers currently perceive or imagine the role of discipline-based education research to be for them?

Research Question 3 (RQ3): What are the motivations and professional development needs of physicists who engage in informal physics?

1.1.2 Operational Definitions

There are content-specific terms and jargon central and prevalent to this dissertation that are defined for clarity as follows:

- **Discipline-based education research (DBER)**: "represents a collection of fields that sit at the intersection of a STEM discipline and education research" [7]. DBER is an inherently interdisciplinary field that combines discipline-based content knowledge alongside education methodologies and theoretical frameworks. DBER has been defined as a field that "investigates learning and teaching in a discipline using a range of methods with deep grounding in the disciplines' priorities, worldview, knowledge and practices. It is informed by and complementary to more general research on human learning and cognition" [8].

- **Science, Technology, Engineering and Mathematics (STEM)**: broad category of scientific disciplines, including ones that are not explicitly stated in the acronym such as physics, astronomy, chemistry and biology.

- **STEM professionals**: Individuals who work in STEM. In this dissertation, this term refers to emerging STEM education researchers and scientists engaged in informal physics.

- **Emerging STEM education researcher**: researcher who gets started in education research after their training in traditional STEM discipline.

- **Agency**: human capability to act independently and effectively over one's actions, behaviors and interactions with themselves and others. In particular, in this dissertation, we use the social cognitive perspective of agency constructed by Bandura[9], which says that agency is an individual's ability to make choices and take action based on intentionality, forethought, self-reactiveness and self-reflectiveness.

- **Informal physics**: activities, events, programs that happen outside the formal classroom environment on physics concepts, phenomena, ideas and discoveries. Many terms are used interchangeably with informal physics, including public engagement and outreach. For the purpose of this dissertation, we use informal physics and public engagement interchangeably. We avoid using the term outreach to avoid the negative connotation associated with the term, which implies a one way interaction between facilitator and audience instead of mutual engagement between both parties[5].

1.2 Map of the Dissertation

1.2.1 Research Approach

There are multiple worldviews that shape approaches to qualitative research: positivism, postpositivism, constructivism, and feminism, just to name a few[10]. This research study will make use of a constructivist approach to research because its aim is to understand how participants are making sense of their experiences in their socio-cultural environment. Constructivist meaning-making and interpretation are based on the premise that all knowledge and therefore all meaningful reality is contingent upon human practices, being constructed in and out of interactions between human beings and their worlds, and developed and transmitted within an essentially social context[10]. Therefore, to create meaning and make sense of an experience, one needs to get an in-depth understanding of the participants in that environment and how they construct meaning through their discussions of behaviors and actions they undertake. Thus, we adopt in this study a constructivist paradigm and choose the theoretical and methodological approaches for each piece of this dissertation accordingly.

As illustrated in Figure 1.1, we are exploring the integration of education research and physics public engagement in the careers of a national sample of STEM professionals. We are interested in how their needs intersect with programmatic supports within their specific environments, as such we use frameworks that focus on socio-cultural interpretation of agency, identity and motivation. Agency and identity are inextricably linked, as one's identity development occurs within one's ability to influence self-beliefs and behaviors, which connects the emerging STEM education researchers projects of **RQ1** and **RQ2**. Motivation and agency are linked in this context since motivation informs a subset of agency. In particular, motivation characterizes motives and self-regulation to engage in particular endeavors, which theoretically links the projects of **RQ1** and **RQ3**. Following the underpinnings of our choices of theoretical frameworks, we use qualitative methodologies that enable us to provide an in-depth analysis of their experiences: a case study and phenomenography for **RQ1** and **RQ2**, respectively; and a user-centered methodology, personas for **RQ3**.

1.2.2 Outline

We structure the dissertation to answer each of the research questions stated in section 1.1.1 and Figure 1.1. In chapter 2, we focus on providing context on professional development of faculty, particularly the professional development program from which the large majority

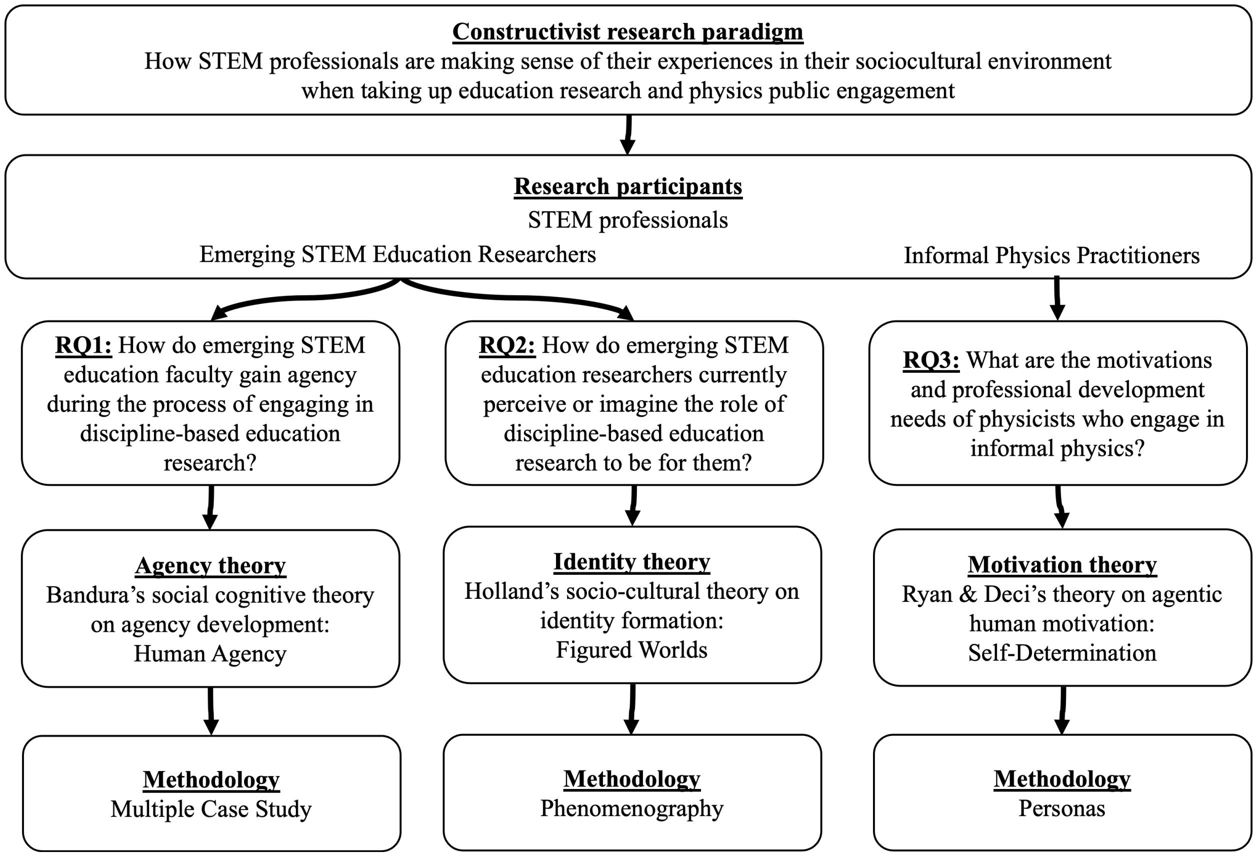

Figure 1.1: *Overview of dissertation: research questions, theories and methodologies*

data was collected for this study. In chapter 3, we address RQ1 and discuss emerging STEM education researchers' agency as they transition into DBER. In chapter 4, we discuss RQ2 where we examine what emerging STEM education researchers imagine or identify the role of education research to be in their professional life. In chapter 5, we provide context on informal physics research and we address RQ3 examining motivations of physicists who do public engagement as part of their professional life and what needs arise as they bring their science outside the formal classroom. In chapter 6, we summarize the main findings and implications of this study in terms of how STEM professionals integrate education research and public engagement in their professional development.

1.2.3 Positionaility

My affiliation and experiences in physics and physics education research as well as the multitude of layers that shaped my professional development journey impact the perspectives by which I conduct my research on the professional development of STEM professionals. Some of the most relevant and significant pieces of my identity and experiences that influence my research are:

- I am an Egyptian Muslim woman who studied in five different countries around the world and two different educational systems and languages. The extremely privileged educational opportunities that I have had access to shape how I understand the scientific process, knowledge conception, meaning-making, learning and teaching in STEM.

- I am a physicist who has been an active member of 3 different types of physics departments in the United States (a Ph.D. granting physics department, a master's granting physics department, and a bachelor's granting physics department). My lived experience as physicist in training in these departments shapes my current understanding of how physics departments operate based on department values, institution mission and priorities.

- I am an emerging DBER researcher at the boundaries of two academic fields, physics and education. These multiple scholarly spaces I accessed while getting my graduate training provide me with a unique research position on the professional development of professionals integrating multiple fields of research into in their careers.

I include these statements because my background inevitably contains inherent biases, affordances, and limitations, which may influence the findings of this dissertation.

Chapter 2

A Professional Development Program for Emerging STEM Education Researchers

The majority of the the work presented in this chapter was published in the 2023 American Society of Engineering Education Annual Conference Proceedings[11].

Many STEM faculty, trained only in disciplinary research, transition into research on the teaching and learning side of their discipline, often after typical formal training opportunities (e.g. grad school, postdocs) are over. These STEM faculty are what we call in this dissertation emerging STEM education researchers. Although there are a variety of existing models for faculty professional development, there are limited opportunities for professional development for this set of faculty when starting education research.

In this chapter, we aim to showcase one of the few professional development opportunities for emerging STEM education researchers to get started in this field: a program called PEER, which stands for Professional development for Emerging Education Researchers. PEER is designed to help faculty at any institution jumpstart their transition into discipline-based education research. Drawing on evidence from participants in the field school, we discuss the various modalities available and discuss the developmental arc of each module.

Afterwards, we demonstrate the impact of the program on participants and how it can help foster the next generation of STEM education researchers. In particular, research on the program has shown the significant impact of the field schools on increasing agency, self-efficacy and sense of belonging to discipline-based education research (DBER) for emerging education researchers, which highlights the relevant features to consider when designing faculty professional development opportunities.

2.1 Overview of Faculty Professional Development

Historically within the context of higher education, faculty professional development has focused on improving the teaching part of faculty's roles[12]. In STEM education, this faculty professional development lens has specifically focused on instructional change to encourage faculty to use more student-centered and active pedagogical approaches in their teaching. In particular, the aim of many of the current faculty professional development programs in this strand is to find ways in which evidence-based teaching practices stemming from research on teaching and learning can be translated into the classroom[13]. The research on these programs and interventions aims to increase their effectiveness by examining the ways in which programs and interventions can be used to help faculty learn and implement research-based practices[14].

The most common teaching professional development is often housed in Centers of Teaching and Learning at institutions, which are non-discipline specific but have resources and workshops surrounding teaching and improvement of teaching. These a-disciplinary and institution-specific professional development resources provide extensive support to faculty for developing a deeper understanding of how students learn by providing general teaching principles. Some also provide mentorship and support to faculty during course development. These centers at institutions also strive to form teaching and learning communities across institutions to provide broad professional development support. For example, the Professional and Organizational Development (POD) Network offers professional development resources and aims to create a community of practice for scholars and practitioners of educational development[15]. Another example is the International Society for the Scholarship of Teaching and Learning (ISSOTL) network which aims to foster and promote collaborative scholarly work about teaching and learning[16]. These many professional development opportunities around teaching development and being more scholarly about teaching are often a-disciplinary and focus mainly on action-oriented research. Some scholars agree that a-disciplinary approaches can be and are sufficient to develop teaching and learning in all disciplines[17]. However many faculty highly value disciplinarity, and see a-disciplinary programs as not applying to them, or not meeting their needs[18]. This causes many faculty to discount or avoid a-disciplinary programs.

Regarding discipline-specific professional development, disciplinary STEM programs, often offered through professional societies, such as AAPT (American Association of Physics Teachers), APS (American Physical Society), MAA (Mathematical Association of America), exist and provide development for disciplinary pedagogical knowledge. These professional development opportunities often help STEM faculty develop disciplinary pedagogical skills, focusing on the implementation of specific research-based instructional practices and curricula. For example, in physics education research, programs such as the Physics and Astronomy New Faculty Workshop (NFW), are aimed at new faculty to help them become more aware of research-based teaching practices[19]. More recent interventions, such as the physics faculty online learning communities (FOLC) were created to support faculty after participation in a teaching professional development program such as NFW, to sustain community support for effective teaching throughout the year[20]. In the mathematics education community, conferences such as RUME (Research in Undergraduate Mathematics Education) were created to encourage research in undergraduate mathematics education and its application in teaching practices in the classroom[21].

Although disciplinary professional development opportunities exist, very few options exist for professional development in research, especially for transitions into new areas of research. One of the professional development opportunities that exist in STEM is the Gordon Research Conferences (GRC), which are meetings where researchers from different scientific disciplines discuss the latest pre-publication research in their field and build research collaborations and community[22]. These conferences are about building bridges across research areas, rather than gaining skills in conducting research in a new area. Another research professional development opportunity that exists for faculty to learn new disciplinary research are workshops on specific techniques or skills for a specific research area offered at conferences such as, in the field of physics, the Aspen workshops[23] and APS research workshops[24]. However, these types of workshops are not as common in STEM education research.

Despite the existence of many faculty professional development opportunities, the options to engage in professional development in discipline-specific education research are not widespread. Some tenured faculty decide to dedicate their sabbaticals to learn about new subject matter and gain familiarity with a field such as education research. However, this option is only available to more senior faculty members. Given the limited opportunities for professional development for faculty at all career stages to get a holistic overview of the various ways to combine disciplinary expertise with formal education research theory and methodology, we discuss in this chapter where PEER as a program fits in and its impact on emerging STEM education researchers before delving into detailed research studies in subsequent chapters.

2.2 Context: PEER Program

PEER stands for Professional development for Emerging Education Researchers. It is a professional development program designed to help faculty, postdocs, and graduate students jumpstart their transition into the world of discipline-based education research[25]. The central activity of the PEER field school is a series of modules to help emerging STEM education researchers develop quality research projects; engage in targeted experiential work to develop their projects and skills; and collaborate and form a support community of peers, mentors and collaborators. As of the beginning of 2023, PEER has run 22 in-person field schools for over 8 years. In its various modalities, PEER has taken place in various places around the world: Germany, Rwanda, Canada, the UK, Mexico, the United States and online.

Participants enrollment has ranged from 10 to 50 for week-long in-person field schools and 50 to 300 in abbreviated online gateway workshops. PEER participants come from a wide range of STEM backgrounds, including disciplinary faculty just getting started on the scholarship of teaching and learning and faculty development experts learning to mentor faculty through scholarship of teaching and learning (SoTL) projects who need mentoring and community support for their research projects.

2.2.1 PEER Principles

This professional development program is based on a set of guiding principles: that research is collaborative, responsive, communicative, and playful. These four guiding principles serve two goals. They are design principles for PEER that facilitators put into practice and they are also framed as research principles for participants to engage in as they get started in education research.

The collaborative principle draws from the communities of practice perspective that stems from Wenger's work. Wenger says that groups of professionals who engage in a process of collective learning in a shared domain of human endeavor are part of a community of practice (CoP) if three characteristics (domain, practice, community) are cultivated[26]. Domain refers to the area of interest, in this context the shared research interest in discipline-based education. Practice refers to shared repertoire of resources (experiences, stories, tools, ways of doing and engaging in work), which in this context is the knowledge and experience sharing around DBER. Community refers to discussions that members engage in around shared practice in pursuit of mutual domain, which in this context is the relationship building that enables participants to learn from each other about DBER. PEER is designed to foster CoPs around DBER.

The responsive principle draws from the responsive teaching pedagogical strategy, which is a student-centered approach to teaching that centers students' ideas and experiences for effective instruction in the classroom[27]. The wide variety of experiences of all people involved in PEER is viewed as an asset that makes the content of PEER field schools different as they adapt to the needs of any given groups of participants and what would be most helpful for their own research interests and trajectories.

The communicative principle draws on the idea that all research happens in conversation with the larger research community. Dissemination of one's work is an integral part of being part of a research community. As such, throughout the entire field schools, writing and discussions occur with the goal of disseminating work to the broader community. Generative writing is a mechanism that is incorporated throughout the field school, underlining the idea that writing at all stages of the research process is part of research.

The playful principle draws from the fluid nature of research, where research will evolve and change as we engage in it and make that process enjoyable. In PEER, this principle is incorporated in the design and facilitation of the modules. Research questions are framed as living questions that will change in various ways throughout the program. Engaging in generative writing is embedded in all modules to generate new ideas. Group discussions are facilitated by asking constructive questions to refine and help participants enjoy the creative ways for their projects to move.

2.2.2 Overview of Module Structure

PEER modules have been and continue to develop iteratively to be as responsive to participants' research and professional development needs. A typical PEER field school takes participants through a development arc. Participants start with refining research interests and field school norms and progress through modules on research process and research ethics. By mid-field school in each modality, participants have done substantial writing and development on their own projects, and they delve into methodological issues of collecting, reducing, and analyzing data from the perspective of noticing ideas (e.g. in classroom video, student free responses, or interviews) and regularizing that noticing (e.g. through generative coding). Near the end of the field school, participants receive deep collaborative feedback from facilitators through the "riff on a project" modules, and they plan explicitly for the next six months of research and development work.

2.2.3 Flow of One Module

A typical flow of a module starts by orienting participants to the topic and learning goals associated with that module; and eliciting their ideas, hopes, and concerns around the module topic. Following this orientation, participants learn about the key ideas of that topic, then they put into practice the skills and/or content knowledge they just learned about through case studies of other research projects, development of their own projects, and/or collaborative feedback with their peers' projects. Finally, most modules end with connecting the skill and content of that module with previous or next modules at PEER, and with extensions to broader perspectives and issues that participants bring. Each module is adjusted to participants' needs and available time using the principles of responsive teaching. Based on the needs and time, 3 different modalities were created following this development arc, which we discuss in the next section.

As an illustration of this flow, we present the data and access module in Figure 2.1. This particular module aims to discuss several common data types and when each one is an appropriate choice. This module also aims to discuss how much data is needed to answer research questions, how choice of data suggests new questions, and how connecting data types to questions refines existing questions.

As we can see in Figure 2.1, in practice, the module begins by orienting participants through a case study linking research questions to appropriate methods where participants brainstorm ideas and share in small groups their ideas (orient phase). In response to ideas elicited by participants, facilitators engage participants in a learning phase where they review the several kinds of data participants read about before the field school began (learn phase). Then, participants revisit the case study they were introduced to in the orienting phase. Following that, the participants get to put in practice their knowledge and skills (practice phase). They discuss a new case study that engages them with the data and scope of a research project. Then, they work on their own projects focusing on choosing data based on access they realistically have and picking specific kinds of data and methods to address their project's research purposes. Lastly, facilitators support participants in connecting data

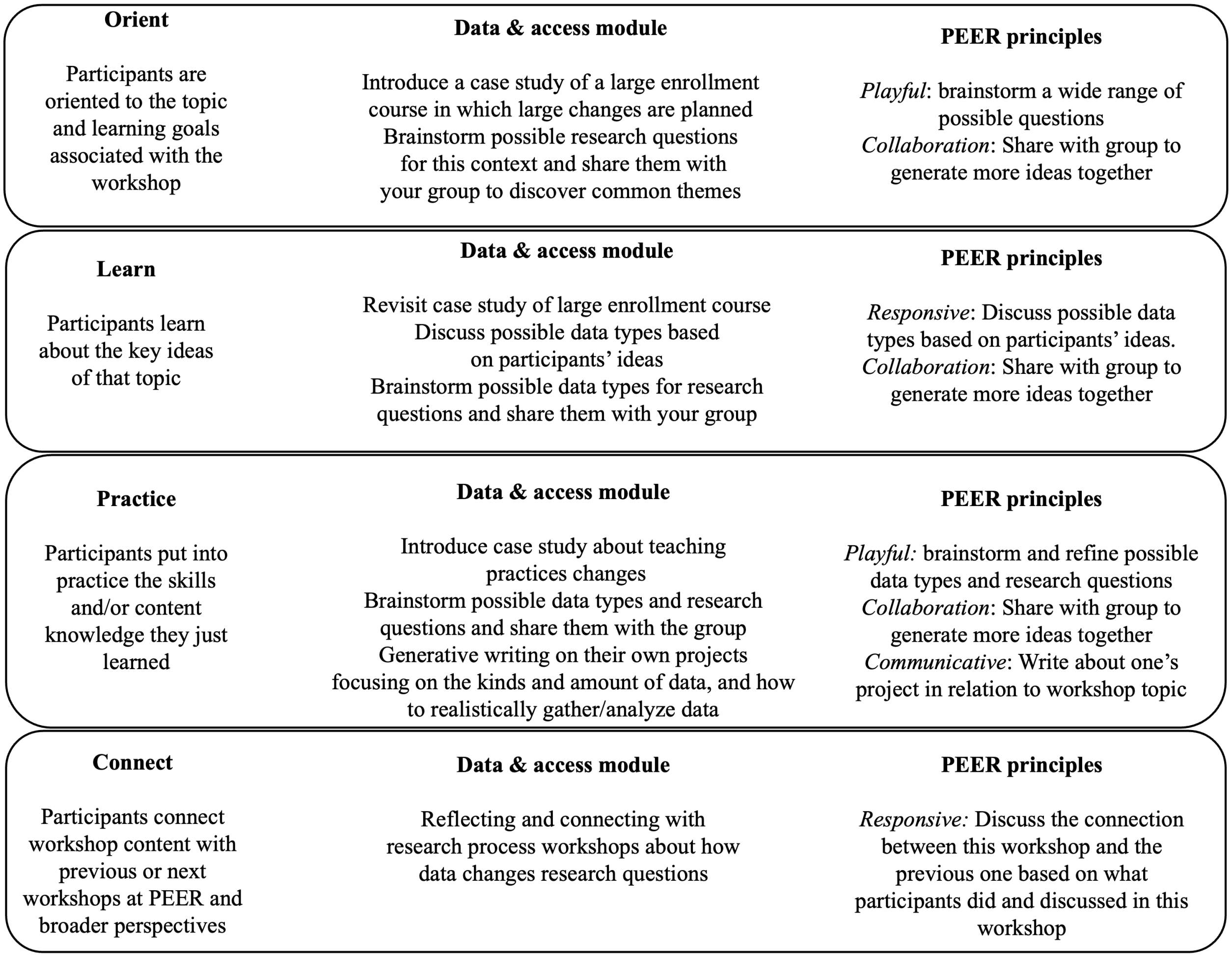

Figure 2.1: *The four phases showcasing the typical development arc of a module using the data and access module as an example and highlighting the PEER principles most at play during each phase.*

and access types to the research process module, showcasing the connection between how the iterative research process presented in that module connects to what participants just did when they thought about how data changes research questions and vice versa (connect phase).

2.2.4 Modalities

The available modalities of PEER field schools developed over the years are: introductory in-person field schools (3-5 days), online or in-person gateway workshops (1.5 hours or 3 hours), and the new advanced in-person field schools (5 days). Each of these modalities is built off collaborative work among participants, blending development of foundational skills in education research with individual progress in their own specific education research projects.

The extended introductory in-person field schools (3-5 days) engage participants with the fundamentals of STEM education research over an extended period of time, with a focus on developing specific independent or collaborative research questions. The first day of the PEER program often starts with the research life category, with modules on field school norms and refining research interests. Participants spend the following days progressing through modules on different facets of the research process, including data acquisition and analysis, methodology, and theoretical frameworks. Near the end of the field school, there are substantial collaborative feedback sessions, and explicit planning for the next six months of research and development work with benchmarks to help them sustain their projects post-PEER. The typical flow of this modality is illustrated in Figure 2.2. The typical enrollment in this modality ranges from 10 to 50 participants. By the end of 2022, PEER has run 22 successful extended introductory in-person field schools and has 3 planned in 2023.

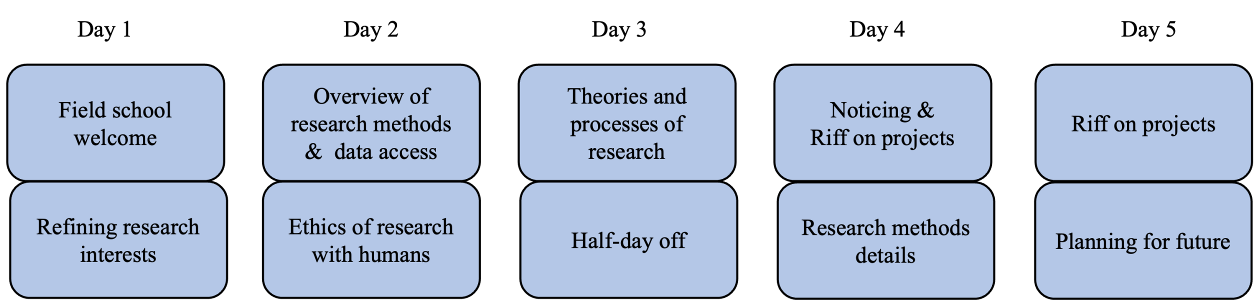

Figure 2.2: *Typical flow and schedule of the extended introductory in-person modules. Each day has two modules for approximately three hours each.*

The online or in-person gateway workshops (1.5 hours or 3 hours) provide an entry point for communities getting started in STEM education research. The typical flow of this modality is illustrated in Figure 2.3. The typical enrollment in this modality ranges from 50 to 300 participants. As of the end of 2022, PEER has run 3 virtual gateways and is planning an in-person gateway in summer 2023.

The new advanced in-person field schools (5 days) follow-up introductory in-person field

Figure 2.3: *Typical flow and schedule of the online or in-person gateway workshops. Gateway workshops are substantially shorter than field schools, so their treatment of these topics is less in-depth.*

schools with focused development on qualitative (emergent coding and video analysis) and quantitative (social network analysis) methods. The typical flow of this modality is illustrated in Figure 2.4. The enrollment in this modality has been around 10 participants. As of the end of 2022, PEER has run 1 advanced field focused on qualitative methods during summer 2022 and is planning another one in 2023.

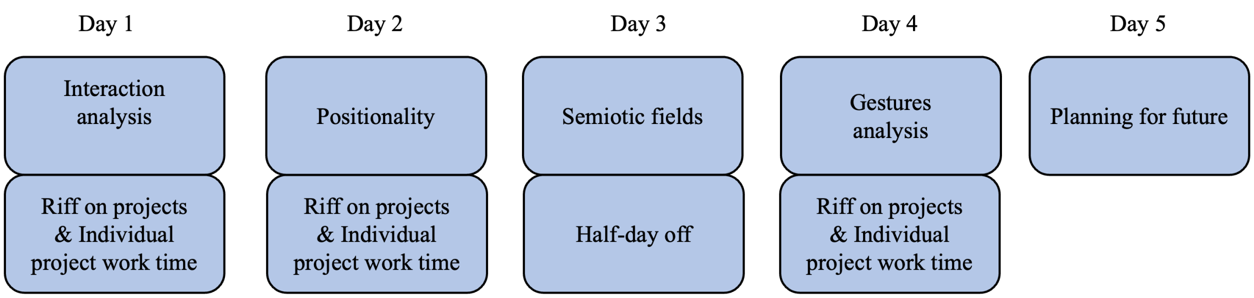

Figure 2.4: *Typical flow and schedule of the new advanced in-person field schools. Each day has two modules for approximately three hours each. Compared to the introductory field schools, the afternoon modules are much more centered on participants' own projects rather than learning fundamental skills.*

2.2.5 Affordances and Constraints of Modalities

The introductory in-person field schools engage participants over a series of consecutive days with the fundamentals of STEM Education Research. This extended time allows participants to have focused and dedicated time to engage with their own STEM education research projects. Working in person promotes interaction among participants, building community and encouraging future collaboration and peer support. Additionally, in-person field schools frequently feature shared meals among participants and facilitators, helping participants make connections to the human side of researchers and the informal interactions that help build community. Furthermore, the combination of the in-person and extended nature allows for on-going and substantive feedback on participants' projects, which the virtual gateway does not allow. However, the large number of participants in these field schools often mean that not everyone gets extended targeted feedback, which makes the reliance on community support through virtual channels (e.g. Slack) important. Moreover, the introductory nature of these field schools means there is not enough time to do in-depth analysis. Modules are designed to be more broad, especially since participants are at different places and stages of their DBER project. Thus, participant progress is more focused on design rather than implementation, which is why the advanced field schools were created to focus on implementation and in-depth analysis.

The advanced field schools come after the introductory in-person field school, and as such enable an in-depth exploration of qualitative or quantitative methods. They build upon the introductory schools, allowing participants to push forward their own research projects with guidance from facilitators. Participants particularly focus on methods, methodologies, and analysis in this modality. This deep dive into particular methods allows participants to develop their competency in these methods. In addition, since participants are required to come in with an appropriate data set, there is more similarity among participants with regard to topic so the modules can be more specific and targeted than the introductory field schools. Moreover, the smaller number of participants in the advanced field schools allows for more specific time and targeted feedback. Nevertheless, participants must have the shared background, skills, and norms from the introductory field schools to participate in this one as it will be challenging for them to delve deep into their own projects' implementation if they do not have the design of their projects set up.

The virtual gateway workshops provide an entry point to attract and motivate faculty to engage in STEM education research. Although it is more challenging to build rapport and community via brief virtual interventions such as this one, the exposure and basic information help spark interest in STEM education research. Their brevity and online nature allow participants from a variety of backgrounds to engage briefly with this field of research, and their online modality makes it accessible to participants in many different countries and time-zones. It is a low-time commitment opportunity and a cost-effective way to raise awareness of the nuances of STEM education to a large number of faculty from different STEM disciplines. In the future, we plan to conduct in-person gateways because they offer the same affordance of low-time commitment and low-barrier for entry. However, we foresee higher costs for in-person gateway unless they are paired with already established conferences or events, such as those provided by professional societies.

2.3 Impact of PEER on Participants

2.3.1 Size and Scope of Interview Corpora

The size and scope of the field school from which we drew interview participants for this dissertation are listed in Table 2.1. Our interview corpora stems from one particular introductory field school that occurred in 2021, primarily drawing from a national audience of emergent mathematics and physics education researchers. This field school occurred over Zoom through spring 2021 and was attended by 45 emerging mathematics and physics education researchers from a variety of research and teaching institutions across the US. The workshop consisted of a kickoff session, three two-hour sessions spread over 6 weeks, and then a three-day intensive at the end of June. For PEER participants who responded positively to our solicitations to partake in our research, we had two interview protocols. The first one was for pre-participation in PEER (see Appendix A) that asked them about their interest in PEER and DBER, their experiences and perception of DBER and expectations from participation in PEER. The second one was for post-participation in PEER (see Appendix B) about their experiences in PEER, their experiences and perception of DBER and their professional identity. Thirteen participants were interviewed pre-participation and eleven participants were interviewed in the post-interviews. Only five participants took part in both pre and post interviews (for a total of nineteen participants).

Our data also contained a set of emerging STEM education researchers who did not partake in any PEER field schools, but were getting started in education research. Since our demographic for this dissertation is STEM professionals who are getting involved in education research, we interviewed some emerging STEM education researchers that were not PEER participants to get a deeper understanding of the spectrum of needs they have and what their career trajectories look like. Interviews participants in this set were housed primarily in two STEM disciplines: math and biology. For non-PEER participant, we had one interview protocol (see Appendix C) asking them about their experiences and perception of DBER and their professional identity. A total of nine participants participated in the non-PEER participants' interviews.

Interviews for all research participants were conducted by the dissertation author and another member of the research team over video conference (Zoom), recorded, and transcribed (professional transcriptionist) for analysis. Two in-depth specific research studies on this data are detailed in chapters 3 and 4, with additional details on data collection and analysis for each project. Nevertheless, we provide in the following section an overview of research results from several PEER research projects.

2.3.2 Overview of All PEER Research Results

In examining the impact of PEER on participants, we identified how transformative the program was on participants' trajectory in education research. Receiving introductory information on how to design an education project, building mechanisms to sustain research projects and engaging with a supportive community helped participants increase their agency in STEM education research (work presented in chapter 3). In our work investigating how emerging STEM education researchers identify and/or imagine their positioning in DBER, we identified how emerging STEM education researchers conceptualize their navigation into education research (work presented in chapter 4). We identified three ways they conceptualize education research: to improve teaching, to join a new field of research, or negotiate their position and identity in DBER vis-à-vis their home discipline. We especially identified that having explicit discussions about the challenges of professional identity negotiation during

Table 2.1: *Research participants' primary academic department, PEER field school participation and interview protocols used during study*

Pseudonym	Pronouns	Department	PEER Field School	Interview Protocol
Ashley	She/her	Math	Introductory field school 2021	Appendix A
Chandrika	She/her	Math	Introductory field school 2021	Appendix A
Emma	She/her	Other	Introductory field school 2021	Appendix A
Jacob	He/him	Physics	Introductory field school 2021	Appendix A
Jessica	She/her	Math	Introductory field school 2021	Appendix A
Lily	She/her	Math	Introductory field school 2021	Appendix A
Mariah	She/her	Physics	Introductory field school 2021	Appendix A
Priyanka	She/her	Math	Introductory field school 2021	Appendix A
Akemi	She/her	Physics	Introductory field school 2021	Appendices A and B
Madison	She/her	Physics	Introductory field school 2021	Appendices A and B
Olivia	She/her	Math	Introductory field school 2021	Appendices A and B
Ryan	He/him	Math	Introductory field school 2021	Appendices A and B
Samuel	He/him	Physics	Introductory field school 2021	Appendices A and B
Ava	She/her	Math	Introductory field school 2021	Appendix B
Marcus	He/him	Math	Introductory field school 2021	Appendix B
Penelope	She/her	Math	Introductory field school 2021	Appendix B
Peter	He/him	Math	Introductory field school 2021	Appendix B
Raya	She/her	Math	Introductory field school 2021	Appendix B
William	He/him	Math	Introductory field school 2021	Appendix B
Alex	They/them	Math	None	Appendix C
Andrea	She/her	Math	None	Appendix C
Brooke	She/her	Math	None	Appendix C
Cole	He/him	Math	None	Appendix C
James	He/him	Math	None	Appendix C
Kaylee	She/her	Math	None	Appendix C
Rebecca	She/her	Math	None	Appendix C
Melinda	She/her	Biology	None	Appendix C
Tabitha	She/her	Biology	None	Appendix C

professional development activities is important to support new scholars finding their place in the field of education research.

Our research on the types of community that members needed to support their transition highlights the importance of having supportive peers, engaged subject matter experts, and effective project managers in emerging scholars' research endeavors to increase their sense of belonging in the field[4]. Our research also explored how challenging it is for new scholars in education researchers to conceptualize theory and navigate how it is used in education research. Emerging STEM education researchers have concerns about legitimacy and acceptable practice within the community as they engage in this new field and tackle certain topics such as theory and theoretical frameworks, which are conceptualized differently than in their primary STEM disciplines[28].

Overall, our research using interview data shows that engaging with a supportive community of researchers and scaffolded program activities can help address emerging STEM education researchers' needs. In particular, professional development opportunities that attend to the unique challenges they face in the interdisciplinary field of DBER allows emerging STEM education faculty to be more connected and engaged in the DBER research enterprise.

We have seen the trends from interview data emerge in post-survey data as well. In particular, post-survey data showed us how the community building that happens at PEER goes hand in hand with the procedural and content knowledge shared among participants and facilitators. As a core principle of the program, it was valuable to see the collaborative principle translate effectively in practice to participants. A participant wrote in post-survey data that *"I really enjoyed the building of a supportive community aspect of PEER!"*, highlighting the value of the rapport and community building that happens at PEER. Another participant highlighted how this simultaneous process of community building and experiential learning really allowed them to move forward by building their network and skills: *"This experience was incredibly valuable not only in helping me consider next steps for my research, but also connecting me to some amazing humans who are now part of my professional network."* Lastly, another participant stressed the value of getting iterative feedback at different stages of their projects from both facilitators and other participants to really engage with the DBER enterprise:

> *I super appreciated the amount of interaction time we got both with the facilitators and other participants who are in the same boat as us. It was awesome to form these social connections and here about what others in the field are up to!*

Moreover, post-survey data showed that how much is covered within a specific modality can have significant impact on participants and the amount covered in each topic as well. For example, one participant shared how *"The theory session was overwhelming."* and others shared how it was still a bit intimidating for them to do DBER, but say they are more confident in their ability to do education research because PEER broke down for them the process into manageable pieces. One participant shared *"I learned that I can do educational research within my context as a mathematics faculty - not only that it is theoretically possible, but that a once daunting possibility now seems more than accessible to me."* By scaffolding their entry into STEM education research into manageable pieces and providing community support from various levels of DBER experiences, participants have increased self-efficacy and competence in engaging in this new field of research. As such, survey data highlights the importance to tailor field school topics and length based on participants' needs, which can vary tremendously depending on their career stages and their priorities based on their local institutional context.

Lastly, one of the goals of PEER is also to have new scholars disseminate their work to the broader research enterprise and further the development of the field. To date, we are aware that ideas and collaborations emerging from PEER participants led to submission of 19 papers, 21 presentations, and 19 posters.

2.4 Implications for Faculty Professional Development

Our goal with the PEER program is to build capacity and community for the next generation of STEM education researchers. In its successive iterations and several modalities, the PEER program has highlighted some important features to consider when designing faculty professional development opportunities.

Our research shows that professional development for faculty cannot just focus on particular skills development but needs to fully incorporate community building for an opportunity to find connections and partnerships with various members in the DBER community[4]. Our research also highlights how important it is to attend explicitly to the needs of each participant. In particular, as STEM faculty become education researchers, they are not only navigating a new research field, they are also trying to see how to fit it within the local needs of their department and institution (work discussed in chapter 4). Thus, attending explicitly to each participant's institution type, department priorities, and career stage is important to help them be successful in their research endeavors.

In this chapter, we presented a professional development for emerging STEM education researchers that is based on important collaborative pedagogical techniques and takes participants through a development arc based on their needs and available time. Although various modalities exist, they are all built off collaborative work among participants, blending development of foundational skills in education research with individual progress in their own specific education research projects. Research on the program, which drew upon interview and survey data collected throughout various iterations of these field schools, has shown the significant impact of the field schools on increasing the agency, self-efficacy, and sense of belonging to DBER for emerging education researchers. While some modalities are more suited to some participants than others, our program shows the importance to tailor field schools topics and length based on participant needs which can vary tremendously depending on their career stages and their priorities based on their local institutional context.

Chapter 3

Emerging STEM Education Researchers' Growth in Professional Agency

The work presented in this chapter was submitted to the International Journal of STEM Education.

In this chapter, we investigate agency development of three emerging STEM education faculty, one in mathematics and two in physics, as they participate in a professional development program to answer **RQ1**: How do emerging STEM education faculty gain agency during the process of engaging in discipline-based education research? We ground our case study analysis of our participants in a theoretical framework on agency. We identify the elements of the professional development program that were transformative in our case study participants ' trajectory in education research, which includes receiving information to get started, building mechanisms to sustain research projects and engaging with a supportive community. These identified program elements that affect agency growth can inform professional development opportunities for STEM faculty transitioning into a new field of research with only training in their discipline-specific science.

3.1 Literature Review

DBER, discipline-based education research, is an inherently interdisciplinary field that combines discipline-based content knowledge alongside education methodologies and theoretical frameworks. DBER has been defined as a field that "investigates learning and teaching in a discipline using a range of methods with deep grounding in the disciplines' priorities, worldview, knowledge and practices. It is informed by and complementary to more general research on human learning and cognition"[8]. One of the main goals of DBER is to advance STEM education to address the increasingly complex and interdisciplinary challenges of society[7].

In recent years, the literature has studied a population of researchers who engage in DBER referred to as Science Faculty with Education Specialities (SFES)[29–31]. SFES refer to university science faculty who not only engage in research in science education, but also in other science education initiatives such as preparing future science teachers and course or curriculum development[3]. Most studies on SFES have focused on individual disciplines efforts in biology, chemistry, geoscience, mathematics, engineering and physics departments, rather than across STEM disciplines[32;33].

The literature on SFES faculty has reported on differences in the origin of SFES positions based on the type of institution the faculty are: at PhD-granting institutions, SFES are hired to relieve other faculty from their teaching load, at MS-granting institutions, SFES are hired to train future K-12 science teachers; and at primary undergraduate institutions (PUI), SFES transition to their role after their hire to fulfill a need in their department[3]. The background and training of SFES faculty are varied and have been changing over the last decade.

Although SFES are now more prevalent and are more likely to be specifically trained in discipline-based education research[34], many faculty only trained in their respective scientific discipline transition during their faculty career in engaging with research investigating the teaching and learning of their discipline[8]. A subset of SFES are sometimes referred to as "boundary crossers" since they want to become more scholarly about teaching and learning while engaging in other areas of research[25]. What we call in our work emerging STEM education researcher refers to those "boundary crossers," however emerging STEM education researcher may not necessarily be SFES.

There is recent research studying challenges STEM education researchers face in finding community in DBER when those STEM faculty are trained in their specific discipline but have not been formally trained in DBER[4]. There is also research that identifies the barriers these STEM faculty may face with other interdisciplinary education research such as the learning sciences community[35]. More research is needed on the type of support they need when entering the field and their growth as emerging STEM education researchers. In particular, taking an agentic perspective in investigating the transition of these researchers is valuable because it allows us to characterize researchers' motivated behavior in alignment with constructs that are most relevant to each researcher based on their experiences that sparked their interest in STEM education research.

In this chapter, we investigate emerging STEM education faculty's transition to DBER to examine the mechanisms by which we can best support them. We address the following research question: **How do STEM faculty gain agency during the process of engaging in education research?** Exploring this question will allow us to better understand the ways in which DBER can be conducted in even more diverse instructional settings and institutions to improve STEM education. We explore this question through a multiple case study analysis of three participants in a professional development program, tracking how program activities affect their agency as researchers.

3.1.1 Agentic Perspectives in DBER

Faculty as agentic individuals in making changes and adopting new teaching principles has become a more common lens by which we investigate faculty professional development. This agentic perspective has been proven to provide valuable insight around their teaching because it highlights the strengths they bring to their teaching as both content and context experts[36;37]. Agency and professional agency have often been used interchangeably in DBER when investigating STEM faculty's agency in instructional change. In particular, agency has often been examined from a particular lens: how individuals have agency within the power and constraints of systems they engage with and how they exert their agency[38]. Less research has focused on faculty's perception of their agency. In this section, we look at how agency has been studied in DBER, particularly in different STEM education fields and how we focus on perception of agency development in this study.

In engineering education, professional agency growth and identity negotiation have been conceptualized in the context of instructional change to examine the enactment of professional agency of instructors given their individual resources and social conditions[39]. Du *et al.* showed how instructors leveraged resources and social conditions to develop their agency and strategies to overcome pedagogical challenges they faced.

In mathematics education, faculty's professional agency has been studied in community colleges classrooms, where it was shown that part-time faculty are less agentive than full-time faculty in taking instructional decisions[40]. Other studies focused on science and math instructors' professional development showed that teacher agency is a key feature in the successful implementation of professional learning communities[41].

In physics education, most research on agency and faculty has focused on different facets of professional agency enactment or growth within the context of teaching. Strubbe *et al.* uses key parts of Bandura's work to develop an analytical framework of faculty agency. Strubbe *et al.* characterize key features of physics faculty agency around their teaching to demonstrate the value of agentic-based perspectives in highlighting faculty's productive ideas they have about student learning and teaching[37]. This research argues that researchers and educators should support faculty agency in their teaching, however, it does not provide the mechanisms by which we can facilitate that support.

Other research in physics education around agency in teaching include work on the Departmental Action Teams (DAT), the Faculty Online Learning Communities (FOLC), the Physics and Astronomy New Faculty workshops (NFW)[20;42;43].

DAT are externally facilitated groups consisting of faculty, students, and staff focusing on creating sustainable departmental change[44]. The research team behind the DAT initiative highlights the value of having agency when they select an educational issue they will address[45]. Nevertheless, DAT explicitly encourages hiring external facilitators for discussions on educational change, which one can argue takes away from faculty's agency in leading change initiatives in their departments.

FOLC are professional development communities built to support instructors in using research based teaching practices[46]. Researchers engaging in studying FOLC have identified possible mechanisms to support physics faculty's agency in teaching. This included focusing on their productive ideas to allow for deep reflection among faculty who participate in these conversations about teaching and educational change[20].

NFW (renamed recently as Physics and Astronomy Faculty Teaching Institute (FTI)[47]) are workshops that aim to improve physics teaching by introducing new physics and astronomy faculty to research-based instructional strategies[48]. In the research around the impact of NFW, researchers underlined the value of creating professional development experiences for faculty by helping develop their agency[19]. However, NFW has historically encouraged faculty to use the results and findings of physics education researchers in their classroom instead of engaging in doing the research themselves, which does not maximize physics faculty's agency in instructional change.

Each of these programs and initiatives address particular physics faculty needs when it comes to instructional and departmental changes: multi-layer facilitation of department instructional change (DAT), community building and peer support in implementing research-based practices (FOLC) and advocacy in using research-based practices (NFW). The research on these program highlights the value of agentic perspectives when examining STEM faculty instructional change. Less research has focused on faculty interested in doing scholarly work on learning and teaching rather than solely implementation of research results.

Hence, we fill a gap in the literature by investigating the perception of agency growth of STEM researchers transitioning into education research. For STEM researchers who have not received extensive training in discipline-based education research, we have minimal evidence of their experiences as they transition into DBER. In particular, our context draws participants from multiple institutions (similarly to NFW) and promotes community development among participants with shared goals (similar to FOLCs). Our case study participants engage in program activities with the intent to bring their growing skills and research projects back to their home institutions.

3.2 Theoretical Framework: Agency

The literature on student and faculty agency is extensive. One of the most commonly used frameworks for studying agency of both student and faculty comes from social cognitive theory. From this lens, human agency theory of development, adaptation and change adopts the view that individuals are products of the interplay among interactions of environment, behavior and self[49]. Bandura's agency lens informs part of the subject-oriented socio-cultural approach to agency growth which posits that the subject of focus is an agentic actor in relation to the social world and agency is temporally constructed within engagements with different tasks[50].

Bandura's work lays some of the foundation for how the definition of professional agency came to be. According to Etelapelto, "professional agency is practiced when professional subjects and/or communities exert influence, make choices and take stances in ways that affect their work and/or their professional identities"[50]. The concept of professional agency focuses on agency in one's career and has been studied in the context of instructional change and teacher education. The four main areas are professional development, education policies, teacher identity development and social justice[51]. These topics overlap and interact with each other as they constitute the major factors that provide affordances or constraints in university faculty's professional agency growth.

In this chapter, we use Bandura's agency framework with a focus on professional agency examining how participants perceive their agency development during their engagement in a professional development program as they transition into DBER. In other words, within the context of professional development, we use Bandura's definition of agency as an individual's ability to make choices and take action based on intentionality, forethought, self-reactiveness and self-reflectiveness[9] to ground our analysis of STEM faculty who transition to DBER. Table 3.1 summarizes the definition of the components from Bandura's framework and how they are operationalized within the context of this study.

Table 3.1: *Definition of the components from Bandura's framework and how they are contextextualized in this study*

Components of the agency framework	Theoretical definition	Contextual definition
Intentionality	Planning for specific actions for the short or long terms to achieve goals	What emerging STEM education researchers plan to do or accomplish with their first DBER research projects
Forethought	Process of setting goals, anticipating actions and consequences to reach desired outcomes	What research tasks emerging STEM education researchers are considering undertaking and what they anticipate they need to successfully complete their first DBER research project
Self-reactiveness	Motivation and self-regulation needed to execute actions planned	What interest in DBER emerging STEM education researchers discuss, especially what drives their intrinsic motivation to engage in DBER
Self-reflectiveness	Belief in one's perceived competence in their ability to undertake a behavior (self-efficacy)	What emerging STEM education researchers perceived competence in DBER to be

Intentionality refers to planning by setting measurable steps for the short or long term to achieve specific goals. When engaging in any research project, deliberate thinking and mapping of the research directions is a common practice. Research has shown that intentionality plays a critical role in mentorship, especially in experiential learning experiences[52]. So when engaging in a first DBER research project, articulating intent and the scale of engagement can help solidify research directions. In our context, we are using it to get a deeper understanding of what emerging STEM education researchers are aiming for by engaging in DBER and how their aims and hopes evolve as they engage in an experiential learning experience.

Forethought, the process of defining specific tasks and their potential impact on target goals, is an integral part of the research process. Forethought allows us to articulate deeper details that provide insight into intentionality. Researchers show how critical the task analysis/strategic planning phase of forethought plays in self-regulating behaviors and motivation in the short and long term[53]. In our context, DBER tasks planning allows us to get a deeper understanding of how emerging STEM education researchers plan to engage in DBER. It provides more details than intentionality and connects with the other components (self-reactiveness and self-reflectiveness). By exploring emerging STEM education researchers' forethought, we can identify what tasks and behaviors they envision needing most to support them in their DBER research project.

Self-reactiveness is the motivation and self-regulation needed to execute a planned action. In our context, we are particularly interested in emerging STEM education reseracher's' intrinsic motivation to DBER. We are drawing on Self-Determination Theory (SDT), a theory about motivation that centers around a learner's agency when making choices to reach desired goals[54] to examine, justify and interpret their development. SDT suggests that three psychological needs: competence, relatedness and autonomy have to be satisfied to have the most self-determined form of motivation[55]. In our context competence refers to the need to feel proficient in engaging in DBER. Relatedness refers to the need to feel connected to the DBER community, the people and the research products value. Autonomy refers to the need to have a sense of choice in behavior and tasks that drive their engagement in DBER. Although we are most interested in understanding intrinsic motivation, SDT draws us to also examine the role of extrinsic motivation, especially how external factors can regulate behavior. These emerging STEM education researchers are engaging in DBER while holding other responsibilities within their respective institutions, which inevitably plays a role in how they view their role in DBER. As such, understanding DBER engagement through the interplay of these regulatory factors can provide insight into their motivation to do DBER and how it evolves as they engage with a DBER professional development program.

Self-reflectiveness refers to a "self reflective belief in one's ability to succeed". In our context, DBER self-reflectiveness allows us to gain insight into emerging STEM education perceived abilities to do research, which can help us understand what support is needed. When looking at self-reflectiveness, Bandura draws our attention to self-efficacy, which is defined as one's perceived skill and competence in their ability to undertake a behavior[56]. Understanding emerging DBER self-efficacy can inform support of what professional development needs would be most beneficial. Bandura's work investigating the relation between agency and self-efficacy underlines how changes in self-efficacy have a direct and critical impact on agency, where increasing self-efficacy is a necessary condition for increasing agency, whereas increasing other aspects of agency does not necessarily entail an increase in self-efficacy[49]. Bandura's theory on self-efficacy also suggests four different sources that contribute to a person's perceived self-efficacy: mastery experiences, vicarious learning, verbal persuasion, and physiological states[56]. In our context, mastery experiences refer to experiences that provide information about personal successes or failures in task similar to the new DBER experience they are engaging in and influence emerging STEM education researchers' confidence in their ability to perform a DBER related task. Vicarious learning refers to learning that occurs by observing others performing DBER either by observing how they are engaging in DBER or how they compare their DBER work with others. Verbal persuasion is related to messages received about their ability to do DBER conveyed through interactions with the DBER community. Physiological state refers to emotional indicators that an emerging STEM education researcher may rely on when evaluating their ability to do DBER.

These four elements of agency: intentionality, forethought, self-reactiveness and self-reflectiveness, are interrelated and combined they provide us with a valuable and holistic lens to study the factors that impact STEM faculty as they transition into DBER.

3.3 Data

The backdrop for this research study is a professional development program, Professional development for Emerging Education Researchers (PEER), which we described in detail in chapter 2. Conducting this study within the context of PEER was advantageous for two main reasons: firstly, our data collection was grounded in participants' experiences with the program; secondly, most participants were leading their first research projects in DBER so it was an opportune time to examine the mechanisms that best support emerging STEM education researchers.

To briefly recap, for this particular study, the data stems from participants in one of the virtual editions of the PEER program, primarily drawing from a national audience of emergent mathematics and physics education researchers. This field school occurred over Zoom through spring 2021 and was attended by 45 emerging mathematics and physics education researchers from a variety of research and teaching institutions across the US. The workshop consisted of a kickoff session, three two-hour sessions spread over 6 weeks, and then a three-day intensive at the end of June. Table 3.2 lists goals and activities of each set of workshop sessions during PEER. As can be seen in the table, PEER is professional development program expecting active engagement from participants where collaboration, responsivity and group work is embedded in all aspects of the program. At the end of each session, participants were asked to list their questions they had and topics they wanted to learn more about. The following sessions incorporated these questions and interest participants had.

Participants were solicited for semi-structured interviews before and after participation. Semi-structured interviews are a common tool for data collection in qualitative research, which uses a series of open-ended questions allowing for emerging themes in the discussion to be explored[57]. Our interview protocols can be found in Appendix A and Appendix B. Thirteen participants were interviewed pre-participation and eleven participants were interviewed in the post-interviews. Only five participants took part in both pre and post interviews (for a total of nineteen participants).

3.4 Methods

A case study as a methodological approach focuses on developing an in-depth analysis of a case or cases to capture the complexity of the unit of analysis[58;59]. When doing a multiple case study, the researcher selects a few case study participants to illustrate the unit of analysis, which is agency.

In practice, the case study analysis was conducted as follows. The first author conducted a preliminary analysis of the interview data, which highlighted participants who addressed the unit of analysis. Three of the five participants who took part in both pre and post interviews were chosen using a purposeful sampling process, a common way of selecting

Table 3.2: *Goals and activities of each set of workshop sessions at PEER*

	Goals	**Activities**
Kickoff Session	Introduce facilitators and participants to establish community and to set expectations and norms about the series of workshops.	Topical discussions: ethics of collaboration Generative writing
Session 1	Work on research design by identifying key features of a research question and recognizing that they change over time and refining it through collaborative feedback and self-reflection on their particular contexts for research and data access.	Topical discussion and procedural knowledge: research questions and data access Generative writing
Session 2	Articulate differences between research models and implications for practice as well as develop a plan for the next steps of your research project.	Topical discussions and procedural knowledge: models of research and topic of interest for participants: literature reviews, data collection and IRB Generative writing
Session 3	Provide feedback on individual projects and help participants understand the impact of their worldview on their research process and research project	Individualized project feedback from facilitators Topical discussions on theoretical frameworks Generative writing
3-Day Intensive	Engage in observational data analysis, theory discussion, individual project feedback and dissemination of work and planning for next steps post-PEER.	Individualized project feedback from facilitators Topical discussions and procedural knowledge: observational data, theory and dissemination of research Project mapping of goals with specific tasks for both the near (days, weeks) and far (months) future Generative writing

cases in qualitative research[60;61]. Our case study participants addressed components of agency and were at different stages of their faculty career as they started to engage in their first education research project in their discipline. Given that these faculty were at a similar stage of engagement with DBER but at different stages of their professional lives, they allow us to investigate variation and similarities in agency growth in education research for faculty with different teaching and research experiences.

After selection, the dissertation author provided a detailed description of themes for each case study participant grounded in Bandura's agency framework. This thematic analysis was expanded to compare and contrast themes across cases to identify the key elements relating to agency growth. After the themes across cases were characterized in the theoretical framework, the dissertation author wrote an initial analysis of the case studies. Then, members of the research team reviewed the analysis together. The instances where disagreement was identified, a discussion followed until agreement was met. This process often resulted in the dissertation author reviewing the interview transcripts to provide more evidence for their interpretation with the relevant pieces of data.

3.5 Case Study Participants

Our three case study participants are given the pseudonyms Olivia, Madison and Akemi. During their participation in this study, Madison and Akemi are leading their first physics education research (PER) project, whereas Olivia is leading her first math education research (MER) project. As they are chairing the first project in discipline-based education research, all three case study participants identified a common need to gain practical skills and a better sense of what the field of DBER was. These beliefs and motivations were a strong reason for their participation in a professional development program such as PEER.

Olivia is a Full Professor in a mathematics department at a public land grant university. She has been in her current mathematics departments for over twenty years teaching introductory and upper-level mathematics courses. Her graduate training is in mathematics and her current primary research area is in graph theory. During her participation in this study, she was exploring mathematics education research to help make evidence based instructional changes in her classroom and institution. In the course of her engagement with PEER, Olivia focused on developing her existing research project and developed an understanding of where she can situate herself in mathematics education research (MER).

Madison is an Associate Professor in a physics department at a primarily undergraduate institution. She teaches many of the undergraduate physics courses, but she is especially passionate about instructional laboratory teaching in physics. Her graduate training is in physics and her current primary research area is in condensed matter physics. During her participation in this study, she started exploring physics education research to inform and assess her work redesigning instructional labs in her department, which included facilitating a departmental faculty learning community. In the course of her engagement with PEER, Madison focused on narrowing down her research questions and getting started on writing an NSF grant to fund her physics education research (PER) project.

Akemi is a Visiting Faculty Member in a physics department at a private liberal arts college during the pre-interviews and a high school science teacher in the post-interview. She was teaching a few introductory undergraduate physics courses and was about to teach high school science. Her graduate training is in physics with a research focus in condensed matter physics. As an early-career scientist during her participation in this study, she was engaging in physics education research to make evidence-based instructional decisions in the classroom as well as build her research portfolio for her career advancement. In the course of her engagement with PEER, Akemi focused on refining her research project and getting started with data collection.

3.6 Analysis

In the following section, we discuss our data analysis within each component of Bandura's framework for each case study participant. We present each participant's pre-PEER status and post PEER status for each component of the framework.

3.6.1 Intentionality

Intentionality in the literature is defined as the planning for specific actions for the short or long terms to achieve goals. In our context, intentionality refers to what emerging STEM education researchers plan to do or accomplish with their first DBER research projects. Features of intentionality were brought up by participants pre and post-PEER, highlighting the alignment of short and long-term plans with motivation. Project mapping at PEER was the central common activity contributing to intentionality. Table 3.3 summarizes the status of intentionality for each participant.

Table 3.3: *Status of intentionality (plans) pre and post PEER for each participant*

Participants	Pre-PEER	Post-PEER
Olivia	**Alignment of short and long-term plans with motivation**: Short-term: complete her MER project about assessing the impact of a new pedagogical strategy Long-term: keep finding ways to measure how to make learning math better for students in math courses at her institution	**Refined conceptualization of short-term plan:** Short-term: submitting a paper and attending an upcoming MER conference Long-term: keep finding ways to measure how to make learning math better for students in courses at her institution.
Madison	**Alignment of short and long-term plans with motivation:** Short-term: go through and complete at least one iteration of the research design of a PER project Long-term: PER fits into her long-term career trajectory where she hopes to incorporate PER in her research portfolio	**Refined conceptualization of short-term plan:** Short-term: obtain a National Science Foundation (NSF) grant for her PER project Long-term: PER fits into her long-term career trajectory where she hopes to incorporate PER in her research portfolio
Akemi	**Alignment of short and long-term plans with motivation:** Short-term: complete her current PER project to have a DBER project to discuss when applying for more permanent jobs Long-term: PER fits into her career prospects	**Refined conceptualization of short-term plan:** Short-term: submission of conference paper and a longer journal paper for her current PER project Long-term: PER fits into her career prospects

Pre-PEER Intentionality

Olivia's short term plan is to complete her MER project about a new pedagogical strategy they are implementing in their calculus courses, which is specific to her institutional context and issues they are having about introductory math courses:

We are basically open admissions, which means we do get a lot of students who *are first generation, low income, and so have nonmathematical readiness issues, [...] so looking at whether or not taking those students with really low prerequisite skills and putting them in a class that's going to provide them with this corequisite support over the course of calculus, that is, to not ask them to drop back to precalculus but keep them in calculus with a little extra support. And we're going to measure whether or not these students with low scores look like they can be successful in calculus.*

By providing background information about the type of institution she is at, Olivia sets the stage for her intention she articulates, which is measuring the impact of providing additional support to students in calculus instead of dropping them to pre-calculus courses. Her long term plan is to keep finding ways to measure how to make things better for students in math courses at her institution by investigating different instructional change strategies. Her intentions to engage in MER is to improve passing and retention rates in math courses. She is supported by her institutional context where she hopes to implement effective instructional strategies.

Comparable to Olivia, Madison's short term plan is to go through and complete at least one iteration of the research design of a PER project in order to be able to write and submit a grant proposal:

I would just really love to come out with some type of completed product of, even if it's like a draft or a logic module or, you know, questionnaires that I can send out. Start getting some concrete documentation and things to prepare for grant submission for this.

PER also fits into Madison's long-term career trajectory, where as a tenured professor, she hopes to incorporate PER in her research portfolio:

Basically, this is my first year as a tenured associate professor, so a question is always what do I do now? What is going to be my next big thing to get me from associate to full professor? And I have my materials research, and I'll continue *to do that, but I really like the idea of kind of adding on to what I do as a way to get myself to that next big step in my career.*

Likewise we have similar factors as part of Akemi's intentions in doing DBER. On the short-term scale, Akemi hopes to complete her current PER project to have a DBER project to discuss when applying for more permanent jobs:

I have a major goal is kind of find what improves or decreases my students' self-efficacy [...]I'm a visiting professor, so I'm not required to do research, but I know I have to do research to get a better job.

On the long term scale, PER fits into her career prospects as she is looking for jobs that will require her to do research. She is considering faculty positions and public engagement positions where doing research on instructional change and best practices would be a core component. Doing and completing a STEM education research project will provide evidence of her expertise when she applies to more permanent positions, which will aid her career advancement.

Pre-PEER in intentionality, we identified that on the long term scale Madison and Akemi wanted PER to become a major component of their research portfolio. Whereas Olivia wanted to keep being involved in improving teaching at her institution and sees that engaging in MER will allow her to do so. To reach those long-term goals, all three case study participants wanted to complete at least an iteration of the research design process.

Post-PEER Intentionality

The process of project mapping helped Olivia identify specific goals and actions that needed to occur and set intentions for the short term, which include submitting a paper and attending an upcoming MER conference:

It both helped me make specific plans to submit a paper, clarify a new research question that is both new to me but also a new kind of skill set I need to address it [...] it helped me clarify what it is, is sort of my more recent research project, *and it's also helped me produce a more specific set of future plans. So, you know, submitting a particular paper, attending a particular conference, that sort of thing.*

In the long term, she plans to continue asking similar questions about improving math education. She plans to remain intellectually engaged in MER by creating master's students research projects with data analysis relevant to her research:

I'm probably kind of committed to a series of short-term plans for now. The other thing that I'm also in a really advantageous position is that my department has a statistics master's program [...] If I can produce data from our institutional database, I can implicitly produce a statistics project for a master's student who needs a statistics project, and so that also helps me kind of keep thinking about some of my questions.

We see in the long-term plans, there is no significant difference in her intentions, but we can notice that project mapping helped refine conceptualization of short term plans. For Madison, her short and long term plans have not changed. However, she articulates more concrete steps in achieving those goals, which came up when she discussed the planning for next steps that happened at PEER. She wants to apply for a PER grant:

I'm hoping over the next six months to work on a grant and that's going to be various steps. I want to start actually just making like visuals for it just to help me process like what is the flow of the project, like the logic models and stuff. And yeah, the big goal for me is one of the like NSF education grants.

Moreover, she still wants to include PER as a main area of research portfolio and is considering dedicating her sabbatical to this endeavor:

Oh, the other like longer, longer term planning thing as well is part of the grant is my kind of strategic career plan. I got a sabbatical I could take at some point, so I would really like to have the money to take like a full year sabbatical to really focus on the education research side.

For Akemi, her short term plan is more specific compared to the pre-interviews. Taking the time to map out her research projects at PEER enabled her to realize that she is at a stage where she is trying to find a good journal home. She is considering submission for a short conference paper and a longer journal paper:

> *I can try a two-page proposal to the International Conference of Learning Science, I believe. That's-[...]So try that and then see how it goes, and then after that, I can try something like PRPER [Physical Review-Physics Education Research], writing a 15-to-20-page stuff. So that's my goal, so I'm trying to put that two-page thing, and then see what I missed.*

Her long term plan is still related to her job prospects but she switched positions during PEER. She is now a high school science teacher and may consider keeping her current position, but it is unclear where PER will fit into that:

> *So I think the thing I'm imagining is more like I collaborate with someone else, and they probably teach at university or college and then I might... Then, I don't know, if I'm researching on my own students, I don't think the IRB will review that. I'm interested in that, but I don't know a way to research on high school students.*

Post-PEER intentions in the short and long terms to improve teaching practices by doing DBER remained the same for Olivia, Madison and Akemi. Nevertheless, they had a more defined trajectory on how they will keep engaged in DBER work post-PEER, especially in their short term planning. The most significant PEER activity in their refinement of short term plans was the project mapping that happened at PEER that allowed each participant to conceptualize the next steps of their projects.

3.6.2 Forethought

In the literature, forethought is defined as the process of setting goals, anticipating actions and consequences to reach desired outcomes. In our context, forethought refers to what research tasks emerging STEM education researchers are considering undertaking and what they anticipate they need to successfully complete their first DBER research project. Unlike intentionality where the participants brought up project mapping, several program activities were brought up by participants when it came to forethought: interactions with facilitators, topical discussions, DBER literature, procedural knowledge and project feedback. However, the common theme pre-PEER in forethought was the common need for research project design support. Given the different stages they were at pre-PEER, there were nuances specific to each case participant's DBER project in the actions they foresee and post-PEER these were refined with the nuances relevant to each. Table 3.4 summarizes the status of forethought pre and post PEER for participants.

Pre-PEER Forethought

Olivia has little interactions with the DBER community, even informally, however she had submitted a proposal to the National Science Foundation (NSF) to examine the ways in which those with very little perquisite skills succeed in calculus class with additional support. She had identified many parts of her research process and identified the areas she believed she needed most help, which are refinement of research questions and writing of a science education grant. She is anticipating refining her research questions by engaging with researchers with various backgrounds in the field. She is also anticipating the need to get a broad view of MER and the different steps of the research design process to enhance her grant writing:

> *So a lot of that sort of the nuts-and-bolts aspects of submitting a science education, math education or sort of community transformation sort of grant is clearly, I'm clueless and I could use help on that.*

In parallel, Madison has had several informal conversations with members of the DBER community. She collaborated with education researchers when she opened up her classroom for data collection for education projects. She has concrete ideas for her research project and knows she needs help refining her research question and project into a tangible and

Table 3.4: *Status of forethought (research tasks) pre and post PEER for each participant*

Participants	Pre-PEER	Post-PEER
Olivia	**Articulates need for nuanced research project design support:** Articulates need for research question refinement	**Articulates refinement of research project design with nuances:** Articulates where her research question fits within the MER field and how to move forward Anticipates potential challenges related to data types and analysis she uses
Madison	**Articulates need for nuanced research project design support:** Articulates need for research question refinement and structure to move research project forward	**Articulates refinement of research project design with nuances:** Articulates how she transformed her general PER interest into a viable PER research question and project Articulates specific research tasks she is engaging in: grant writing Articulates need to continuously engage in professional development that helps her move her research project forward
Akemi	**Articulates need for nuanced research project design support:** Articulates need for research question refinement, need for structure to move project forward and need for guidance on data analysis	**Articulates refinement of research project design with nuances:** Articulates how she transformed her general PER interest into a viable PER research question and project Articulates specific research tasks she is engaging in: data collection and analysis

viable study. She anticipates the need for guidance with different steps of the research design process. In particular, articulating and refining her research interest into a viable PER project:

I'm coming in with kind of a concrete idea, I would love it if it's almost like stepping me through what the project should look like. Like, helping me take what I have and think of ways of okay, how do I go with this kind of nebulous idea of faculty learning communities and labs, and how do I do take all these steps we're going to talk about, like how do you assess the grant, how do you come up with good research.

Unlike Madison, Akemi has had few interactions with the DBER community, but she is collecting data in her classroom to pursue her research interest. She has identified the need to better understand the structure of how to conduct DBER research as someone unfamiliar with the research field. She put together a proposal to conduct a research study to promote equity in her physics classroom but wanted guidance on refining her research questions. She also highlights needing help with data analysis to move forward with her research:

I do want to learn how to analyze my data, I believe there is something about like coding stuff like that, but I don't really know how to code my data. So yes, that's definitely something that I want to learn.

In forethought pre-PEER, we examined the common need that all three participants identified: research design refinement, particularly the refinement of their research questions. However, there were nuances in their stages of the research process. Olivia applied for a grant from the NSF so she had made an attempt to identify all the different parts of the research design process. Akemi had put together a PER study proposal at her institution that was accepted and she was already in the data collection phase. Madison had interacted peripherally with PER projects by welcoming researchers into her classroom to collect data. She had identified a research interest, but she had not put together the pieces of her research design.

Post-PEER Forethought

For Olivia, by interacting with other STEM researchers through the workshops and the MER literature, she describes having a better sense of the DBER community. Readings and interactions with other participants at PEER has broadened her understanding of MER as a mathematician. It has also broadened her perception of what is MER, who does MER and how she perceives the field. She foresees herself playing a useful role bridging the disconnect that can exist between mathematicians and mathematics education researchers. PEER has also helped her articulate some specific actions and consequences she is anticipating as she continues to move forward with her MER project. Although she anticipates finding time to do DBER in her schedule challenging, she views time constraints as keeping her accountable. She will be encouraged to continue her interactions with the DBER community in the near future to complete her current MER project:

> *I'm going to be forced for the next three years to be reaching out to DBER people in some form. And sort of periodically reevaluating whether or not I'm reaching my goals, not just with the project but more broader, like the things I specifically talked about, keeping in contact with people I've met and continuing to broaden my reading.*

She also anticipates some criticism of her work from the broader DBER community because her quantitative analysis does not depict a complete picture of students' progress in their math courses and she anticipates the need for qualitative lens. For Olivia, the PEER activities that played a role in her growth in forethought were interactions with facilitators with DBER expertise, topical small group discussions and guiding engagement with DBER literature.

As for Madison, different elements contribute to her growth in forethought. She has a better sense now of what a viable education research process is and how to transform research interest into a research project in PER. She foresees seeking out similar interactive professional development programs that focus on participants' specifics research projects:

> *[PEER helped identify] how do you go about transforming something you might be curious about into something that's a viable research project? And I really like that. [...]Even if it was just like webinars or something, I would love to continue to engage with this because I feel like the workshops were... I like that they were*

> *really interactive, I like that they gave us a lot of time to work on our projects ourselves and I would love to do that in like a more guided sense.*

Obtaining get-started information has provided her with a roadmap on how to move from research interest to a viable research question and project in DBER. She has learned how to articulate her research question and refine it through the many successive opportunities in the PEER workshops that broke down the tasks related to DBER into manageable pieces. In particular, the PEER activities that played a role in her growth in forethought were procedural knowledge workshops, topical small group discussions and individualized project feedback from facilitators.

For Akemi, obtaining information on how to get started has provided her with a roadmap on how to move her research project forward. She has gained insight into the significance of the different parts of the research design process such as theory and limitations. She values how explicitly DBER people think about the limits of their understanding, which she did not see much of in condensed matter physics. She believes that she has a far better idea of what her project is and how to move forward with it, as compared to before doing PEER. To situate her work within the field, she anticipates framing her papers in a similar structure to the PER literature she has been engaging with. She anticipates being better at assessing work related to her research topic because she has a good solid background on the foundational work in her research interest area:

> *I think, I mean, if I see some new theory, I'll definitely pay more attention about to learn that. If they are talking about self-efficacy and they are not using Bandura, it's like Bandura is everywhere and then so currently, I haven't found anything new on the theory that I'm doing, but if I find a different one, I would use that as a keyword to find more paper.*

For Akemi, the PEER activities that played a role in her growth in forethought were mainly procedural knowledge workshops and gudiment engagement with DBER literature.

Workshop structure, content and community at PEER helped research project refinement for Olivia, Madison and Akemi. For Olivia, workshops that addressed refinement of research questions iteratively, setting specific DBER plans for the near future addressed aspects of the research design she had identified needing pre-PEER. For Madison, the iterative process of the research design that participants went through at PEER helped her refine her research design. She has also identified more specific parts of the research design she will want help with in the future. For Akemi, through readings and discussions, she learned about the norms of the field and how to situate and shape her project within it.

3.6.3 Self-reactiveness

In the literature, self-reactiveness refers to motivation and self-regulation needed to execute actions planned. In our context, self-reactiveness refers to what interest in DBER emerging STEM education researchers discuss, especially what drives their intrinsic motivation to engage in DBER. Similarly to forethought, a common interest motivates participants in engaging in DBER and multiple program elements affect growth in self-reactiveness. However, more program elements are highlighted and impact the nuances of self-reactiveness post-PEER than forethought. Table 3.5 summarizes the status of self-reactiveness pre and post PEER for participants.

Table 3.5: *Status of self-reactiveness (sources of motivation) pre and post PEER for each participant*

Participants	Pre-PEER	Post-PEER
Olivia	**Competence and relatedness** drive motivation to improve teaching by doing DBER.	**Competence and autonomy** still drive motivation to improve teaching by doing DBER; refined conceptualization of short-term plan.
Madison	**Competence, relatedness and autonomy** drive motivation to improve teaching by doing DBER	**Competence and relatedness** drive motivation to improve teaching by doing DBER; refined conceptualization of short-term plan
Akemi	**Competence** drives motivation to improve teaching by doing DBER	**Competence and relatedness** drive motivation to improve teaching by doing DBER; refined conceptualization of short-term plan.

Pre-PEER Self-reactiveness

For Olivia, competence and relatedness are the two components of self-determination theory that help her the most in doing DBER at her institution. She wants to do MER to increase her competence in teaching to increase student success and persistence in math courses. She also wants to relate her research results from her classrooms to her institution:

> *The driving force for me, and I know that math educators often don't really want to talk about this in this way, has been to see students be more successful. Specifically, to pass at higher rates and to continue sort of to the next course at higher rates. And what, you know, I'm not interested in just what happens in my class, I'm interested in what happens at the institution.*

To have productive conversations about instructional change in her department, Olivia wants to use the results of her own research-based findings from MER. This refers to the relatedness of doing this type of research as it provides a means to communicate with evidence based, context-specific ways, her research results to her colleagues:

> *You know, all my colleagues are math professors, which means you can't just walk up to them and say, "hey, let's try this thing." If you don't start with something that's evidence based, if you're not starting from a point of scholarship, you're not going to get started.*

This last excerpt also underlines the value and the potential impact that DBER scholarship can have in bringing many faculty members part of her department on board in making instructional change. Olivia also wants her math department and university to find better ways to assess student learning, which ties into the self-regulation component of self-reactiveness. She is supported in her DBER engagement because of its potential to addresses critical and current needs at her institution: it is a context-specific, yet research-based way to improve success and retention in mathematics courses.

Similarly competence, relatedness and autonomy are all elements that motivate and self-regulate Madison's engagement in DBER. In terms of competence, Madison wants to become a better physics teacher by improving her classroom practices. She describes doing PER is a way for her to become better at her job:

> *I've also found myself really interested in physics education research, both as, you know, using it to help inform my teaching, but also, I'm just interested in learning more about how to be a good physics teacher.*

Features of autonomy and relatedness are discussed when Madison describes the freedom to pursue various new teaching evidence-based strategies in the classroom:

> *So I feel like there's been a lot of freedom there to pursue different teaching routes and, you know, this comes up in things like tenure and promotion too. Like, our department puts, I think, a good deal of weight and will give you a lot of credit for going and trying these new pedagogy.*

She articulates that research-based teaching practices are valued in tenure and promotion evaluations. This external regulation provided by her department motivates engagement in instructional change. PER is encouraged due to its potential benefits for student learning in a primarily undergraduate institution that attracts underrepresented groups and wants to best prepare them for their post-undergraduate careers.

As for Akemi, competence is the most prominent component of self-determination theory that motivates her to engage in DBER. She wants to do PER projects to create more equitable learning environments for students in her classroom. She wants to investigate the ways in which she can increase self-efficacy of underrepresented students in her physics courses:

> *I'm interested in that [doing physics education around promoting equity] because I found like minorities in classrooms are usually either lack of self-efficacy, a lack of confidence, or the opposite, they think they are good, they don't know that they are bad at this stuff. So I just I'm interested in like how my students are doing and how they are thinking, and I think [doing a PER project around] that [can] help.*

Akemi does not articulate the ways in which her PER work will be evaluated or the ways she will assess her own endeavors in this new field of research for her. This is most likely due to her being currently in a temporary faculty position during this interview as she says that she is a visiting professor and is not required to do research.

Pre-PEER in self-reactiveness, we identified that Olivia was motivated to do MER to improve passing and retention rates at her institution. Madison wanted to be a better physics teacher by engaging in PER to improve her classroom teaching practices. Akemi wanted to create more equitable physics classrooms so engaging in PER would allow her to investigate the interplay between self-efficacy and underrepresented populations in physics classrooms. Olivia and Madison related their motivation to the value of doing DBER would bring to convincing colleagues of instructional change, benefiting students at their respective institution and getting recognized for this type work in promotion and tenure evaluations.

Post-PEER Self-reactiveness

For Olivia, competence remains a primary motivator. She continues to want to improve teaching by doing MER at her particular institution. In terms of self-regulation, Olivia discusses her autonomy as she is reflecting on some of the discussions that occurred at PEER around mentorship and ways one can discuss the value of DBER in a department that may not be supportive of this type of research. She recognizes how much freedom she has compared to less senior faculty in pursuing DBER: doing a research study, getting results, making recommendations to her department about changes and being heard. Although she is already at an institution that values math education research, she is not expecting rewards from her school to motivate and regulate her engagement in MER. This integrated regulation is considered the type of extrinsic motivation regulator that leads to the most autonomy[54], which shows how Olivia has a high level of autonomy in her MER work. The PEER activities that played a role in her growth in self-reactiveness were topical small group discussions and interactions with a range of career stages.

Similarly for Madison, increasing competence remains a major motivator for pursuing

PER. Improving teaching practices for the type of students her institution attracts informs her education research interests. Through self-reflection on the societal impact of her job, she hopes to help the student population of her institution get the most out of their education. Improving physics laboratory courses allows the development of technical skills that can be useful for students as they search for jobs after they graduate. The main PEER activity that played a role in her growth in self-reactiveness was generative writing regularly throughout the workshops.

Through different programs elements than Olivia and Madison, Akemi refines her interest and her research project's focus. Her motivation to do PER is still about equity in physics classrooms. By talking to facilitators and engaging with the broader PER literature, she finds ways to specifically enhance her project by situating her work within the vast array of research published about self-efficacy of students in physics classrooms and gender equity[62;63]. Given that she is in-between two temporary teaching positions, she does not elaborate on the ways she will be evaluated in her research endeavors. The PEER activities that played a role in her growth in self-reactiveness were interactions with facilitators with DBER expertise and guiding engagement with DBER literature.

All three case study subjects were consistent in their motivation behind their reason to transition into doing DBER. For Olivia, engagement with participants at PEER further highlighted her freedom to pursue MER at this stage of her career and institution. For Madison, self-reflection on her impact as a physics instructor deepened her motivation to engage in PER to improve learning outcomes for her students. For Akemi, situating her work within PER helped her refine her interest.

3.6.4 Self-reflectiveness

In the literature, self-reflectiveness is defined as belief in one's perceived competence in their ability to undertake a behavior (self-efficacy). In our context, self-reflectiveness refers to what emerging STEM education researchers perceived competence in DBER to be. Similarly to growth in intentionality, forethought and self-reactiveness, growth happened in self-reflectiveness. However, there were more program elements that came into play in this component, making self-reflectiveness the agency component with the most growth. Table 3.6 summarizes the status of self-reflectiveness through pre and post PEER for participants.

Table 3.6: *Status of self-reflectiveness (self-efficacy) pre and post PEER for each participant*

Participants	Pre-PEER	Post-PEER
Olivia	**Low self-efficacy in mastery experiences:** Looking for mastery experiences	**Higher self-efficacy rooted in multiple sources of self-efficacy, especially:** Vicarious learning and mastery experiences
Madison	**Low self-efficacy in mastery experiences:** Looking for mastery experiences	**Higher self-efficacy rooted in multiple sources of self-efficacy, especially:** Physiological state and mastery experiences
Akemi	**Low self-efficacy in mastery experiences:** Looking for mastery experiences	**Higher self-efficacy rooted in multiple sources of self-efficacy, especially:** Verbal persuasion and mastery experiences

Pre-PEER Self-reflectiveness

Olivia expresses low self-efficacy when she describes her NSF grant proposal process she applied for to engage in MER. She did not ask for help from some of her colleagues because she feels unqualified to do MER compared to them despite collaborating with them in other areas of research:

> *So the one thing I remember about is my professional colleagues that I didn't collaborate with. Yeah, so the issue is... So I have, I would say, three colleagues, two of whom I've actually written research papers in mathematics with, who have done a lot of math ed grants, actually quite a few. And I did not partner with them [...] I was embarrassed. I know so little about it, even less, you know,*

and I have to admit, you know, I knew I was doing something for which I was unqualified.

Her perception is that she does not have the experience that some other people she knows have when it comes to math education grant writing. Vicarious learning, which emphasizes performance comparison, nurtures this sense of low-self-efficacy. Mastery experience is another reason for her sense of low self-efficacy. Compared to her math research, she feels unqualified to do math education research because she does not know how to turn all her research interests into research projects, which a task she is confident in doing in her graph theory research.

Similarly, Madison articulates that she lacks confidence in doing PER because she does not know how to carry out the different aspects of the research design. In terms of mastery experiences, she feels that she lacks competence in carrying out this type of research compared to her ability to do so in her experimental physics work:

I think I would really, really love to be more confident in myself for my ability to design and carry out an education research project. Like, especially from the nuts and bolts of the education research side of things.

Akemi also articulates low self-efficacy when she describes being unaware how to structure the research process. Even though she has put together a proposal that got accepted and she is already engaging in data collection in her classroom, her confidence in her ability to perform PER is low. She expresses throughout the transcript not knowing how to move forward with different steps of the research process if she gets stuck.

In self-reflectiveness pre-PEER, there was a common trend of low self-efficacy among all three case study subjects, especially in terms of mastery experiences.

Post-PEER Self-reflectiveness

Olivia feels that she knows more about MER because she engaged with the MER literature and received informational knowledge about procedures of MER at PEER. This addresses mastery experience as she feels she can draw from her rich experience in math research herself to contribute to the field of MER. In turn, she feels more comfortable reaching out to collaborate with others because she has a better sense of what she can do for a project. Performance and experience comparison with researchers with various backgrounds at PEER, vicarious learning, contributes to her sense of higher self-efficacy:

> *I at least have read some math education research. I at least have gone to a workshop where I learned about some things. I'm not totally ignorant about qualitative research and various kinds of surveys and various things like, you know, getting IRB approval and that sort of thing. I'm not just a complete dead weight to someone else who's doing DBER research, if that makes sense. I don't want to be dead weight*

Post-PEER, her confidence level is higher. She articulates the ways she feels that she can bring something useful to MER and serve as a bridging role among communities. She feels more confident in engaging with the MER community. The PEER activities that played a role in her growth in self-reflectiveness were interactions with facilitators with DBER expertise, interactions with a range of career stages, guided engagement with DBER literature and procedural knowledge workshops.

For Madison, increase in self-efficacy is seen through the way she describes the impact of receiving concrete get-started information about PER. Narrowing down her research project to specific steps to write a grant proposal has helped her increase her sense of mastery experience, in turn her self-efficacy:

> *So one of my big goals from this whole thing was like to feel confident enough that I could write a grant for my project. And I feel comfortable, much more comfortable now, that I could put a grant together because I have a much better awareness of like the literature I should be looking for and stuff like that. So that was really nice. Yeah, for me, a lot of the skills are the like what do you... Like, I am much more confident in my ability to start a project.*

Spending time articulating her research interest into a research question has also contributed to her gain confidence in the work she is doing, addressing the physiological component of self-efficacy:

I feel really, really good and confident that I came out with some idea on okay, how do I go from it's something I might be interested in to carving that into a research question and start to get the research done.

The PEER activities that played a role in her growth in self-reflectiveness were guided engagement with DBER literature, topical small group discussions, procedural knowledge workshops and taking the time to do project mapping of goals with specific tasks for both the near (days, weeks) and far (months) future.

For Akemi, it was comforting to get feedback on the work she was doing and how it may be useful to the DBER community. Given that she is new to the field, she feared that she might have missed someone else's publication. Verbal persuasion, which occurs when Akemi gets real time constructive feedback from peers and facilitators, plays a positive role in increasing her self-efficacy:

So I kind of asked them whether I should... So I say, I've already my project on how oral quizzes impact students' self-efficacy, and then they told me oh, it's an interesting project, and then it's not been done. So I think that's very important information because I'm new to the education, to this field, and although I've already did the literature survey and did not find something similar, I always worry like whether I've missed some publication

Verbal persuasion occurs when Akemi discusses how supportive the feedback at PEER was. She feels that people were enthusiastic about and valued her ideas:

I feel like, I don't know, I don't feel this often, I hadn't felt that my opinions are valuable in research for years. At least that's not my general feeling in my PhD research, so when I kind of talk [...] they[facilitators] really value what I said, and I think that really boosts my self confidence in this area, like feel I can do educational research like that. So I think that helps a lot.

Feeling valued in her research endeavors is an element of PEER that boosted Akemi's self-confidence because she had not felt it in her condensed matter research during her graduate studies. Engaging in regular generative writing really helped her increase her sense of competence, mastery experience:

> *"I'm looking at my project, "okay, I can write something out of it," and then the generative writing sections are really helpful. I don't know how to do that at the beginning, it's painful to write, I really hate writing. But now I can really sit down, wow, I can keep typing for one hour, or like half hour. It's something that I could not imagine me doing, so I think there's definitely some change in my ability to move my project forward.*

The PEER activities that played a role in her growth in self-reflectiveness were interactions with a range of career stages, individualized project feedback from facilitators and generative writing.

For Olivia, engagement with PEER participants and facilitators, specifically discussing similar interests and comparing experiences with others at different stages of their DBER projects, increased her self-efficacy. For Madison, getting informational knowledge and turning her research interest into a research question translated into gain in self-efficacy. For Akemi, supportive real-time constructive feedback allowed to situate herself within the field and feel welcomed in this field of research, which boosted her self-efficacy.

3.7 Discussion

The key results of our analysis are summarized in Table 3.7 where we highlight program activities as affecting participants' agency, within the theoretical framework. In the table, project mapping refers to mapping of goals with specific tasks for both the near (days, weeks) and far (months) future. Topical discussions refers to topical small group discussions. Facilitator interactions refer to interactions with facilitators with DBER expertise. Career-stage interactions refer to interactions with participants in range of career stages. Project feedback refers to individualized project feedback from facilitators. Generative writing refers to writing as a generative process to keep track of research process, ideas and next steps. DBER literature refers to guiding engagement with DBER literature. Procedural knowledge refers to procedural knowledge workshops.

Table 3.7: *Case study participants highlight program activities affecting their agency, identified within the theoretical framework.*

Theory	Olivia	Madison	Akemi
Intentionality	Project mapping	Project mapping	Project mapping
Forethought	Facilitator interactions Topical discussions DBER literature	Topical discussions Project feedback Procedural knowledge	DBER literature Procedural knowledge
Self-reactiveness	Topical discussions Career-stage interactions	Generative writing	Facilitator interactions DBER literature
Self-reflectiveness	Facilitator interactions Career- stage interactions DBER literature Procedural knowledge	Topical discussions DBER literature Procedural knowledge Project mapping	Career-stage interactions Project feedback Generative writing

3.7.1 Interactions within Participants for each Aspect of Agency Growth

Faculty professional development is highly dependent on home institution type, department priorities, and faculty career stage. As such, to understand how participants develop their agency in this new area of research, it is interesting to see how agency components evolve depending on each participant particular career stage and context.

As a Full Professor in a math department, in the course of her engagement with PEER, Olivia focused on developing her existing research project and developed an understanding of where she can situate herself in mathematics education research (MER). The most noticeable growth in agency occurred thanks to her engagement with participants at various career stages and with various DBER expertise. This engagement really highlighted the autonomy she has as a Full Professor in her research endeavors in MER, leading to growth in self-reactiveness. This also translated into growth in self-efficacy as she was able to articulate what she could contribute to the field when engaging with both the math and math education research communities.

As an Associate Professor in a physics department, Madison focused on narrowing down her research questions and getting started on writing an NSF grant to fund her physics education research (PER) project to expand her research portfolio. As a tenured professor, she has some leeway in pursuing different research interests, especially when finding evidence-based practices contextualized in her department is increasingly becoming a priority for her institutions. The procedural knowledge and the time to reflect and articulate her research interest during PEER led to growth in forethought and self-reflectiveness, leading to overall gain in agency.

As an early-career professional, in the course of her engagement with PEER, Akemi focused on refining her research project and getting started with data collection for her project to see where PER could fit within her career trajectory, which led to overall growth in the agency. Mentorship and guidance from PEER facilitators, increased her sense of competence in self-reflectiveness and refined her motivation in self-reactiveness to pursue her research projects in PER.

Although we see agency growth for each participant in this study, this exploratory analysis draws upon self-reported data of three faculty's experiences, which cannot be generalized to all emerging STEM education researchers. Future work should include other participants' experiences to explore contrasting experiences with agency growth, especially for STEM faculty at different career stages and at different types of institutions.

3.7.2 Program Activities across Theory Elements

Exploring the impact of program activities across agency components provides evidence of activities that impact agency when designing a professional development program.

Supporting activities in the growth of self-reactiveness were discussions of similar interest with participants and facilitators, engagement with key DBER literature and opportunities for self-reflection. Growth in intentionality occurred through the setting of specific DBER plans for the future, which enabled participants to break down research projects into specific and measurable steps to move forward. Growth in forethought occurred through receiving get-started information, engagement with peers, engagement with the DBER literature and the division of tasks into manageable pieces with multiple iterations. All these elements provided participants the opportunity to refine their projects and anticipate specific actions and consequences they foresee as they move forward with their projects.

One or a combination of sources of self-efficacy contributed to growth in self-reflectiveness. Verbal persuasion learning through getting real time constructive feedback translated to self-efficacy increase. Vicarious learning through comparison of researchers' expertise with various backgrounds contributed to an increase in self-efficacy. Mastery experiences occurred through transformation of general interest to specific questions and receiving procedural knowledge about the field. Articulation of realistic and specific addressed the physiological component of self-efficacy.

Bandura says that self-efficacy is one of the strongest components in agency growth during change and adaptation in the workplace[49]. It is not surprising that increased self-efficacy echoed more broadly to gain in other areas of the agency framework. Nonetheless, varying and overlapping activities resonated with participants, which showcase various possible ways a professional development can contribute to increase a sense of agency in a new research area.

Program elements discussed in self-reflectiveness are the only ones that span across all other components of agency (forethought, intentionality, self-reactiveness). Our case study participants articulated the ways in which built-in within the structure of PEER are activities and interactions that address each component of self-efficacy. These elements of PEER that increase self-efficacy carry over to the three other components of agency, leading to overall gain in agency. Program elements in forethought, intentionality and self-reactiveness stem from any exposure to the research process. They are not unique to getting started in DBER, exposure and engagement with a research community will inevitably refine ideas in each of those areas. However, what we find is that the PEER program provides structure to these elements that seem to resonate quite strongly with participants. PEER provides the space and community to be an agentic emerging STEM education researcher. PEER facilitates engagement in research tasks that jump start emerging STEM education research transition into DBER, especially when they have extensive training in other areas of research and experience in teaching. Thus, STEM faculty who already have extensive training in research and myriad of teaching experiences in their specific discipline can chair their first research project in DBER when agency is a central tenet of the professional development opportunities they engage in.

In contrast, some program elements such as the setting of expectations norms and some procedural workshops (e.g. observational data and theory workshops) were not brought by these three case study participants. In this analysis, they were not factors explicitly affecting their agency. However, this does not mean that these activities do not affect other participants' agency and/or have a programmatic impact that leads to agency growth. First, the expectations and norms setting puts forward the principles of PEER for participants engagement and community building, which makes this professional development opportunity an experiential learning experience in which agency growth happens as a consequence of that. Second, the specific workshops not brought up may not have impacted agency development for these participants, but may have done so on others depending on where they are at with their research. If their research interest is not immediately tied with observational data, it may not have had a significant enough impact to be brought up during interviews. In addition, we are looking at growth and some topics such as theory that are overwhelming and an area of struggle for emerging education research[28] may not be brought up in this analysis lens.

DBER's interdisciplinarity and the myriad of ways it is conducted can be challenging for new researchers interested in the field. For emerging STEM education researchers, finding professional development that addresses their concerns from an agentic perspective is a need that must be fulfilled. Support structures can come in various ways, but our research shows the process by which a professional development opportunity worked in favor of increasing self-efficacy and echoed more broadly into agency. This agency growth can sustain engagement in DBER and increase DBER research in different institutional contexts and improve STEM education through effective evidence-based practices that stem from the particular needs of the institutional contexts in which the research interest orignates. To build capacity and community for STEM education research, the DBER community should create professional development opportunities that focus on supporting agency in engaging in DBER, particularly self-efficacy, for STEM emerging education researchers.

3.8 Conclusion

To improve STEM education, some STEM faculty jump start their transition in DBER at different stages of their career. To support their endeavors to conduct DBER in different instructional settings, our study identified elements of a professional development program that increase agency. Our case study analysis showed that addressing one or a combination of self-efficacy sources echoed into growth of other components of agency. This overall gain of agency enhances emerging STEM education experiences in this new field of research for them.

Chapter 4

Figured Worlds of Emerging STEM Education Researchers

An abbreviated part of the work presented in this chapter was published in the Proceedings of the 17th International Conference of the Learning Sciences 2023[64].

Various experiences bring STEM researchers to DBER, but there is little research on their conceptualization of and navigation into this new area of research. In this chapter, we use phenomenography to analyze interview data collected from emerging education researchers to answer our **RQ2**: How do emerging STEM education researchers currently perceive or imagine the role of discipline-based education research to be for them? Grounded in the figured worlds theoretical framework, we identify the spectrum of ways emerging STEM education researchers identify or imagine themselves in DBER: to improve their teaching, to make it their new primary research field, and to negotiate how this new research field will fit with their primary one. We highlight salient negotiations they are encountering in their DBER engagement, which provides us with a better understanding of the opportunities needed to better support emerging STEM education researchers' professional development. In particular, figured worlds allows us to articulate two ways in which there is a special relationship between DBER and disciplinary science. First, engagement in DBER often stems from experiences as discipline faculty, which highlights the challenges of navigating in research areas outside their PhD or postdoctoral training in which their academic identity is formed. Second, the interdisciplinary nature of DBER that spans beyond discipline expertise, yet is rooted in particular conceptions of knowledge and norms found in STEM disciplines, creates a blend of norms and ways of doing things in DBER that is perceived as different by traditionally trained scientists.

4.1 Literature Review

DBER, discipline-based education research, is an interdisciplinary field that investigates discipline-specific learning and teaching that is often paired with more general research on human learning and cognition[8] and has substantial overlap with the learning sciences. Individual STEM disciplines have investigated a variety of topics within DBER with the goal of improving STEM education. Although there has been an increase in formal DBER training programs (e.g., graduate degrees), many researchers have limited formal training in it. We are especially interested in these emerging STEM education researchers who are just getting started in DBER.

The literature has studied a population of researchers who engage in DBER referred to as Science Faculty with Education Specialities (SFES)[29;34]. SFES have been conceptualized as individuals contributing to STEM education reform from a wide variety of academic position types in STEM departments[32]. Most SFES work examines the experiences of faculty-level researchers hired into STEM departments to do education work. However, SFES does not count all people who do DBER. For example, researchers, classically trained, at small institutions can start doing DBER to help with the pedagogical mission of their institutions and their experiences are not captured within SFES research. In parallel, although there is an increase in graduate degrees and postdocs in DBER, there is a substantial portion of researchers who do it without formal training in it. This is what we call emerging STEM education researchers. We are especially interested in emerging STEM education researchers who are just getting started in DBER.

Various STEM disciplines investigated professional development of their communities within the DBER scholarship. Researchers in mathematics, biology, and physics education have examined the impact of interventions and programs on the professional development of their faculty[19;20;45;65;66]. Given the various communities faculty engage in and experiences they bring, conceptualization in each discipline has focused on particular facets of their professional development. The mathematics education research community has investigated the different ways communities of practices can support faculty in making changes in their teaching[67]. The biology education research community studied the tensions in professional identity as scientists and pedagogical reform as teachers[68]. The physics education research community showcased the importance of an agentic and holistic approach to professional development of physics faculty[36;37].

Our work investigates how emerging STEM education researchers identify and/or imagine their positioning in DBER. Their positioning has not been examined before; rather, prior work focuses on the way emerging STEM education researchers' projects evolve. The spectrum of reasons that bring researchers to DBER is valuable to pursue as it allows us to better understand their experiences as emerging STEM education researchers, their interactions with the DBER community, and the diverse ways they perceive DBER's role as a research area. Taking up an identity and positioning frame to better understand the adjustment of new DBER scholars, we address the following research question: **How do emerging STEM education researchers currently perceive or imagine the role of discipline-based education research to be for them?** We interview 28 emerging STEM education researchers and present an analysis that focuses on how they negotiate this research field fit into their professional lives. In turn, these results provide insight into opportunities for support structures and resources for their professional development.

4.2 Theoretical Framework: Figured Worlds

Figured worlds is a theory that captures how individuals imagine or identify their identity and position within a particular context that is social, cultural, and historical[69]. Figured worlds allows us to examine identity formation as an evolving narrative or storyline constructed due to interactions within a sociocultural space. The identity formed within a figured world comes from participation in its activities and from processing the meaning of one's identity in a given socio-cultural context.

The framework underlines four features to characterize the figured world of an individual or a group of individuals as they negotiate their identity[70]. *Recruitment and development* refer to the features of how people process entry and growth as learners in a new sociocultural space. *Meaning creation* is about how they make sense of the space's norms. *Positioning* is about how they situate themselves and the contributions they bring. *Social organization* is how they perceive the power dynamics at play.

Individuals are often part of multiple figured worlds that come together to shape their experiences. There are a range of ways that the figured world can be articulated: particular groups of professionals, particular classrooms, and particular institutions can all be characterized as figured worlds. For example, universities can be characterized as figured worlds, as they are spaces grounded in discourses and practices that are socially, culturally, and historically shaped and in which academic and disciplinary identities are formed[71]. DBER, as a field of research, can be characterized as a figured world because it has the four characteristics that a figured world explores. First, individuals are recruited or enter this field and the field evolves as a result of the work of its members. Second, practices and activities within the field create meaning for its members. Third, the field is socially organized; people learn how to relate to each other within the space based on what is expected and valued. Fourth, individuals identify themselves within the space themselves based on actions taken and the field's discourse.

A feature highlighted in Holland's work on figured worlds is identity in practice, formed and reformed through activities and events that individuals part take in[69]. Holland does not centralize identity in the cultural sense, which often studies the role of demographics information such as gender and race, but Holland focuses on development of identity in relation to practice and activities individuals engage in. Holland states that the significance to the concept of figured worlds "is the situatedness of identity in collectively formed activities. These identities that concern us are ones that trace our participation, especially our agency, in socially produced culturally constructed activities"[69]. Holland distinguishes between three types of identities: relational, positional and figurative. The interplay of these three types shape and reshape the figured world of an individual. Relational identity, often mediated through speech/communication, refers to who we are in relation to our interactions with others. Positional identity refers to one's position relative to others and socio-cultural structures. Figurative, or narrativized, identity is about one's perception of what a particular person is: what they imagine a particular person is in a given cultural world. The imaginative and identification aspect of figurative lens from figured worlds is one of the features of identity that is unique to figured worlds and focuses our analysis on individuals processing and perceptions as they conceptualize their navigation into new fields.

When exploring new research areas, discussions about one's professional identity are at play, including the interplay of relational, positional and figurative identities. Professional identities are constructed within social and cultural worlds, which academia is and often multiple professional identities are intertwined and impact one's professional development[72]. In particular, disciplinary identity which encompasses how individuals understand themselves, interpret experiences, present themselves, wish to be perceived, and are recognized by the broader professional community in their discipline[73]. As such, using figured worlds allow us to focus on how individuals process their professional identity development as they engage in DBER.

Figured worlds has been used in education research to study identity production and explore the socio-cultural contexts in which particular academic, disciplinary, and professional identities emerge[70]. The figured worlds framework has mostly been applied to early career populations such as students, language learners, and new teachers. The work on students has focused on the identity trajectories of underrepresented populations in the sciences, highlighting the discourse and resources necessary to be leveraged for their persistence[74], as well as on how individuals perceive and blend different identities and experiences to make sense of their socio-cultural space as they transition among different settings in their careers[71]. The work on educators has focused on interpreting early career trajectories in different professional careers[75].

The value of this framework is its illustration of the new and different possibilities that individuals figure for themselves within the worlds they are part of[76]. The use of figured worlds allows us to articulate emerging STEM education researchers' conceptualization of and navigation into DBER, particularly how their entry is shaped by their own histories, their involvement in professional development opportunities, and the larger context of their social and cultural environment. By examining what brings researchers to DBER, particularly their figured DBER world, we illustrate the range of ways newcomers imagine its place in their professional lives to be. In particular, figured worlds brings to the surface what is perceive as important to newcomers as they negotiate entry into a new research field, which provides the DBER community with knowledge of the perceived culture of the field to newcomers and opportunity to address the perceptions and challenges newcomers may have.

4.3 Context and Methodology

Our study data involved the same corpus described in chapter 2, which includes emerging STEM education researchers who participated in PEER and emerging STEM education researchers that were not involved in PEER but were transitioning into education research. We used the complete set of 28 emerging discipline-based education researchers for this study.

We analyze this data using a phenomenographic approach. Phenomenography is a research methodology examining how individuals experience a phenomenon[77]. Developed within educational environments, the goal of phenomenography is to describe the variation in people's experiences around a phenomenon. It has been used in physics education to examine students' problem solving approaches in introductory physics[78], to characterize students' conceptual understanding of particular physics topics such as electric and magnetic interactions[79], wave-particle duality[80] and more broadly students learning experiences in the physics classroom[81]. Phenomenography has also been use to characterize experiences of physics faculty's as it relates to their beliefs and approaches to instructional change[82;83]. Outside the DBER context, phenomenography has been used in the higher education literature to study academics' way of conceptualizing research, particularly capturing the different ways faculty and graduate students understand the nature of research and academic work[84;85].

The benefits of this methodology is that allows us to bring to the surface all the ideas that individuals have about the phenomenon studied[86]. In doing so, we gain insight in the multitude of ways people are experiencing a phenomenon, which can uncover contradictions in one's reasoning and open up the possibility to consider alternative ideas[77]. Additionally, phenonmenography can be useful when examining a phenomenon that is hard to define, complex, or could have a variety of meaning[87] because it can highlight the diversity of ways people experience a particular transition and/or learning experience. Raising awareness of this variation opens up the possibility to be more inclusive in supporting individuals' various experiences.

Given that in our study, the phenomenon we are exploring is the transition into DBER at different career stages and in different contexts, we used phenonemography to capture the myriad of ways emerging STEM education researchers conceptualize DBER and view themselves in it as a result. Pairing phenomeography as methodology with the figured worlds theoretical framework allows us to bring to the surface the typical stories around the socio-cultural context that "are usually unconscious and taken-for-granted "[88]. This is an important strategy in order to gain a better understanding of the experiences of emerging STEM education researchers' and identify the opportunities for more inclusive and supportive professional development.

In practice, we applied the phenomenographic approach by engaging in the iterative process illustrated in Figure 4.1. Through the repeated reading of the interviews, categories of experiences were identified across interview participants. We grounded our search of categories in the components of the figured worlds framework (recruitment and development, meaning creation, social organization and positioning). We were paying attention to how participants were discussing their experiences as it relates to these components. After category identification, we created codes and sought nuances within categories to identify subcategories. Moving back and forth between data and categories of experiences led to the creation of the initial set of codes and definitions that formed the codebook. The first author gathered all the quotes and characterized them in the codebook, refining definitions and codes continuously. The first author provided the codebook and 10 % of the quotes to another researcher to check reliability of the codes, definitions and characterization of quotes. The IRR researcher independently coded these quotes. Before discussion, there were 72% agreement between the first author and the IRR researcher. After discussion, which consisted of providing more context from data about the quotes and refining the language and meaning of the codes, the first author and IRR researcher reached 98% agreement. Lastly, the analysis was collaboratively discussed until consensus developed among the project's researchers and extended research team. For illustration, an excerpt of the codebook is presented in Table 4.1 to show one of the categories of experiences identified, the codes and definitions associated with it. Quotes from the transcripts and more details are discussed in the next subsection.

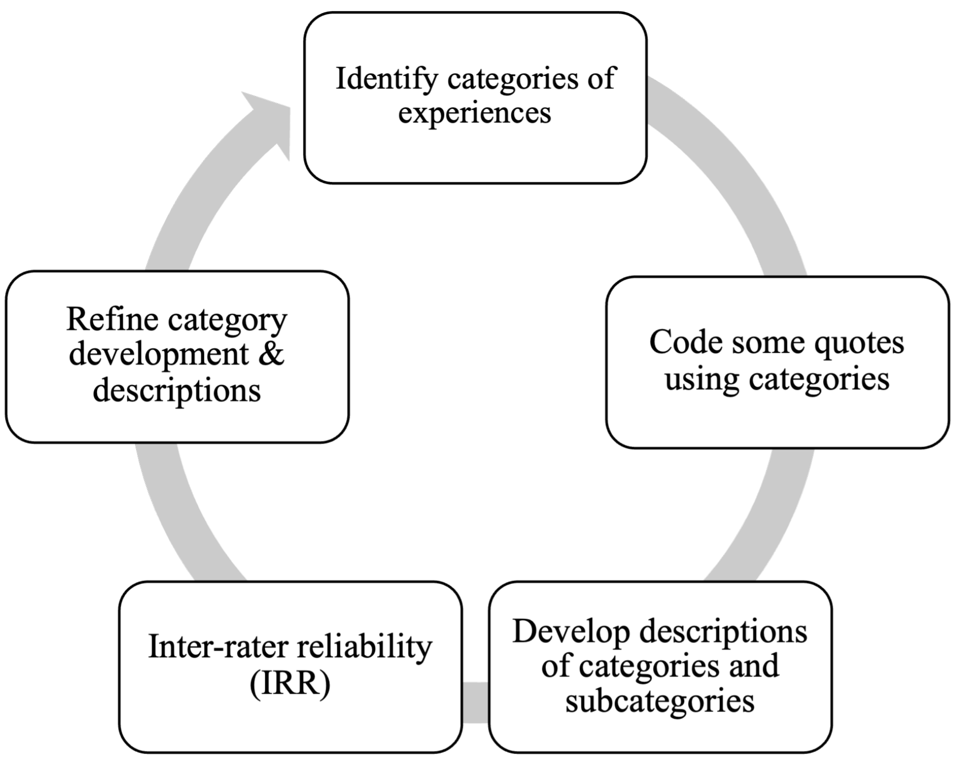

Figure 4.1: *Phenomenography process*

Table 4.1: *Excerpt of the codebook: one of the categories of experiences, codes within that category, and their associated descriptions*

Category of Experience	Codes	Definitions
Improver	Improving classroom practices	This emerging STEM education researcher wants to do DBER to improve classroom practices to increase student learning in STEM classrooms.
	Improving departmental teaching practices	This emerging STEM education researcher wants to do DBER to make research-based changes in their curriculum and departments.
	Improving effectiveness of service work to improve student sense of belonging in STEM classrooms	This emerging STEM education researcher wants to do DBER to improve a particular aspect of their service, which they forsee as translating to their classroom environment.

4.4 Analysis

How emerging STEM education researchers conceptualize their navigation into DBER draws upon all four features of the figured worlds framework. We identified three ways they conceptualize education research: to improve teaching (Improvers), to join a new field of research (Joiners) or negotiate their position and identity in DBER vis-à-vis their home discipline (Negotiators). For Improvers, the DBER figured world is about improving teaching by engaging in education research. For Joiners, the DBER figured world is conceptualized as a space they want to fully engage and grow in as professionals and not just use to fulfill current job responsibilities. Negotiators conceptualize DBER as a space for exploration, but they are still figuring out how to navigate the cultural and procedural norms between their home discipline and DBER.

From the 28 participants interviewed, there were 200 statements belonging to conceptualization of DBER figured worlds. 70 statements for Improvers, 101 statements for Joiners, 29 statements for Negotiators. Some quotes were coded with only a label (for example, only

"Improvers" label and no additional description). Some quotes were coded with a label and a description (for example, "Improvers" label and "enhancing classroom practices "). No quotes were coded with just a description, however, some quotes have one label and two descriptions.

4.4.1 Improvers

The improver category highlights 3 kinds of DBER figured worlds emerging STEM education researchers engage in as they conceptualize entry in DBER as growing from their professional work as teaching faculty and department members. Improvers see DBER as an opportunity to improve practice locally in an evidence-based way.

Improving classroom practices

This emerging STEM education researcher wants to do DBER to improve classroom practices to increase student learning in STEM classrooms. One Assistant Professor in mathematics at US private institution says:

> *I think as a teacher I'm always wanting to try new things. And reading about best practices and I'm always wanting to, yes, to try out new ideas in my classroom and see if they will address some of the concerns I have or some of the issues that I've noticed. And so this desire to better serve my students leads me to want to analyze in some more rigorous way how I'm serving them and how to better do so and use evidence-based strategies.*

. This emerging STEM education researcher wants to find more scholarly approaches to improving their teaching because of their first hand experiences in the classroom. The opportunity for reflection on their own teaching beliefs and practices, and to become a better instructor is informing their entry into the figured world of DBER. The meaning creation they are assigning to their DBER figured world stems from assigning significance and importance to teaching. As such, the simultaneous roles of teacher, researcher and participant they foresee as they engage in DBER is an opportunity to be more intentional and thoughtful in their decision-making processes as an instructor. Although they want to approach instructional change with a research-based approach, their lack of familiarity with established DBER researchers translates into low self-efficacy. An Associate Professor of mathematics at a public US research university within this subcategory shares

> *I feel like a collaborator who really knows what they're doing would be helpful. I feel like as I'm doing this, I'm kind of just making it up as I go.*

This emerging STEM education researcher is positioning themselves within the DBER figured world as a peripheral member wanting support from more experienced researchers in DBER. This need for collaborators, mentors and peers on education projects is a similar challenge identified with previous research on this population that characterizes these roles for emerging STEM education researchers to support their sense of belonging in the community[4].

Improving departmental teaching practices

This emerging STEM education researcher wants to do DBER to make research-based changes in their curriculum and departments. One participant, who is a Full Professor in mathematics at a US public university says:

> *I want our department, and myself as a teacher, to make good choices about what we do in the classroom, how we structure our curriculum, that sort of thing. So I'm interested in making informed decisions and making those decisions in a context in which we can decide if those are good decisions or not.*

This emerging STEM education researcher is engaging in DBER because they want to become more scholarly about instructional and curriculum changes in their particular department. The scope of their DBER figured world is broader than just their classroom environment, it is department wide. However, their DBER figured world remains a means by which to improve their teaching. Nevertheless, despite this department's goal to improve teaching, another emerging STEM education researcher within this subcategory, a Full Professor of mathematics at a US public university, describes the lack of formal training in education research as a perceived barrier to transition into DBER:

> *I think I have contributions to share with the RUME [Research in Undergraduate Mathematics Education] or the PERC [Physics Education Research Conference] community, and I'm not trained in that. And so sort of being able to do education research or talk with people that do education research seems like a requirement to share those ideas with those communities.*

This challenge is described as a lack of familiarity with norms and resources of DBER, but also underlines the image the DBER community projects to emerging researchers. Similarly to the first subcategory of improver, this emerging STEM education researcher is seeking support from the broader DBER community outside his local context since his local environment is not a barrier to his engagement in new research endeavors. This processing of their recruitment and development of their DBER figured world showcases how the DBER community is projecting the value of extensive training in DBER to be heard and make meaningful contributions to the field, without necessarily offering many pathways to transition and resources after training in other STEM fields. Hence, concurrent with other research studies[89], DBER may need to be more welcoming of people at various career stages into DBER as well as provide more resources to get started in DBER.

Improving effectiveness of service work to improve student sense of belonging in STEM classrooms

This emerging STEM education researcher wants to do DBER to improve a particular aspect of their service, which they forsee as translating to their classroom environment. This emerging STEM education researcher who is an Associate Professor of mathematics at US public university is interested in looking at the

> *impact that outreach may have on students' identity as well as students' ability to be successful in their mathematical work within the classroom. So trying to*

make that connection to how that enrichment experience impacts their long-term academic success.

The service part of their faculty role is central in informing their interest in DBER. They imagine DBER as a tool to help them enhance the impact and effectiveness of informal work on students' science identity, which as a by-product can help improve their sense of belonging in STEM classrooms. However, this emerging STEM education researcher faces resistance as they engage as an emerging STEM education researcher in their department:

My chair told me earlier this summer that, you know, 'education research should be done in the college of education. That's what they're for, right? We're a department of mathematics and statistics, so we should do mathematics and statistics.'

DBER is not valued or supported by their local environment and is not viewed with the same caliber as their research in their primary STEM discipline. As a result, the social organization of their DBER figured world contains strife with members outside of DBER, yet shape their daily professional life in their departments. Despite the value they foresee from measuring the effectiveness of informal science on students' sense of belonging in STEM, the lack of understanding of DBER by their traditional STEM department makes their transition to DBER challenging. Although they foresee meaning to their engagement in the DBER figured world, their departments is negatively shaping the way they imagine themselves in DBER by discouraging their involvement.

Although there are nuances in Improvers' conceptualization of their figured world, their figured world of DBER is conceptualized as space that stems from their professional work as teaching faculty and department members, but their imagination and identification are challenged by existing interactions with their departments and/or DBER community.

4.4.2 Joiners

The joiner category highlights 2 kinds of salient reasons emerging STEM education researchers engage in as they conceptualize entry in DBER. These STEM researchers want to fully engage in DBER as an activity and as a community beyond their department and institutions. Their transition process and development into DBER is facilitated by their interactions with the DBER community and their institutions' expectations. Their DBER figured world is conceptualized as a space they want to fully engage in and grow as professionals and not just use as a means to improve teaching practices at their institutions.

Joining an interdisciplinary field and a supportive community

This emerging STEM education researcher is joining DBER because they want to fully engage with this research area as an activity and as a community as they have had positive interactions with the DBER community. One participant, who is an Associate Professor of physics at a US undergraduate institution says:

> *The physics education research field has been so welcoming to just someone who's an outsider that's just curious. You know, even when I was just like a curious outsider, they've been really nice to me. So like it seems like a welcoming field and that's one thing that's drawn me to it and my burgeoning interest in doing this research myself.*

The positive interactions with the DBER community opened up the possibility for them to identify with the field. The processing of their recruitment and development into the DBER figured world made them imagine themselves part of the community. Additionally, another emerging STEM education researcher in this subcategory expands on this reasoning by articulating the value they see in connecting multiple disciplinary identities together to offer insight into the world they are joining:

> *I'm really interested in, you know, what I am bringing as a mathematician to the understanding of math education research.*

They are processing their DBER figured world by imagining the different possibilities of connecting ideas, concepts, perspectives from traditional STEM disciplines and education research. It is an opportunity to create new understanding and knowledge in creative ways.

The playful and creative ways of knowing and understanding that can come from interdisciplinary work and the positive interactions with the DBER community are shaping their DBER figured world.

Joining DBER for action-oriented research in a supportive institution

This emerging STEM education researcher imagines integrating DBER in their research portfolio as it is supported by their institution. An Associate Professor of mathematics at US public university describes how their institution is providing space to engage in DBER to fulfill the institution's mission:

> *I'm at a teaching-focused institution, which means that research is very broadly defined, research can include math education research or teaching-specific research as well as undergraduate-led research, and then also the traditional kind of math research papers in pure mathematics or applied mathematics research.*

Exploration of this new research area is possible because their current institutional environment is focused on improving teaching and supports a broad category of scholarship, which gives them the flexibility to engage in new research areas. Their institution promoting and valuing a broad range of activities within the umbrella of scholarship fuels their imagination of the DBER figured world. Another participant who is a lecturer in mathematics at public US research university expands beyond the institution's mission and elaborates on the value of the tangible results of DBER:

> *And one thing that was exciting to me about that is kind of the feeling of how, this is actually like an impactful career, like this is something that's making a difference, a very tangible difference.*

This emerging STEM education researcher imagines DBER to be a meaningful research career. The direct results they get can be applied to their students to benefit student learning and improve their experiences in STEM education. Their DBER figured world is a space in which they can contribute meaningfully.

Although there are nuances in Joiners' conceptualization of their figured world, their DBER figured world is a space they want to fully engage and grow in as professionals and not just use to fulfill current job responsibilities supported by the possibilities of scholarship in their institution and the encouragements of the broader DBER community.

4.4.3 Negotiators

The negotiator category highlights 3 kinds of salient negotiations emerging STEM education researchers engage in as they conceptualize entry in DBER. Their DBER figured world is trying to find their position and identity in DBER vis-à-vis their home discipline and what DBER will do for them.

Negotiating positioning in DBER and DBER collaborations

Some Negotiators seek to balance improving their teaching and engaging in DBER as an activity. A Full Professor of mathematics at a regional undergraduate serving US institution reflects on the ways to position himself in DBER as a collaborative field. He wonders, *"What's the way to work with education research or what's the overlap"* between doing DBER himself or collaborating with DBER researchers as an engaged instructor, and how he can be *"part of that community"*. He is trying to figure out how to collaborate with education researchers in productive ways but is unsure of what expertise is valued in DBER and what a STEM researcher can contribute. Assigning significance to types of activities and practices within DBER by drawing from past experiences in their home discipline aligns with how figured worlds are formed[69]. However, the navigation of norms of collaboration and scholarship in an interdisciplinary field such as DBER is daunting to emerging scholars in the field, even for experienced researchers in other areas. Creating and finding productive research partnerships is how researchers come to understand how a research field organizes itself. However, this negotiator underlines a challenge in approaching those collaborations, which impacts how they position themselves in DBER and how they see it as a figured world.

Negotiating identity in DBER

This subcategory of STEM education researcher is negotiating which aspects of their professional life drive their DBER engagement. In the interviews, one of the participants who is a mathematics instructor at a US public research institution reflects on her professional identity as having tension between mathematics and mathematics education research:

> *I was a mathematician, but no, I'm not a mathematician anymore. Oh, and maybe I'll be a math ed researcher? No, I'm not really a math ed researcher either.*

This researcher no longer identifies with their past experiences, particularly her training as a mathematician, which influences her lack of identification as a mathematics education researcher. This back-and-forth regarding which disciplinary identity fits is brought to the forefront in the DBER space. While this negotiator sees these two identities as sequential and exclusive, other identity negotiators want to keep both professional identities active. DBER identity becomes a mediating force that causes them to reconsider and renegotiate their professional identity. Although it is common to belong to multiple figured worlds and for figured worlds to evolve over time[71], this subcategory of negotiator stresses that juggling among practices and activities in different figured worlds leads to a challenge in their conceptualization and navigation into the DBER figured world.

Negotiating tension between DBER and traditional STEM disciplines

As a field, DBER promises to improve teaching and learning[8]; however, many STEM faculty are skeptical that its results are as robust as decades of teaching experience[90]. This tension between research and practitioner expertise[91] complicates DBER figured worlds for our participants. One tenured math professor in a mainly undergraduate US institution stresses that some senior mathematicians and faculty *"don't value math education research."* She imagines senior mathematicians saying *"you can't possibly capture what I know from my two decades, three decades, five decades of experience. Like, math education researchers just can't do it."* Part of her figured world of mathematics includes devaluing education research results, as embodied in these imaginary-yet-powerful experienced mathematicians. As this subcategory of negotiator imagines herself engaging more in DBER, she anticipates discovering more of *"those culture fights that have been existing that you don't even realize that you are stepping into."* This is not an uncommon tension that exists among interdisciplinary education research[92], but it is especially challenging to navigate for individuals getting started in DBER.

4.5 Discussion

Emerging STEM education researchers conceptualized their DBER figured world with nuances, which are summarized in Figure 4.2. The variation of experiences that emerging STEM education researchers highlights the features shaping their DBER figured world in their respective environments. Improvers, Joiners and Negotiators are discussing challenges and opportunities that are related and can be mutually reinforcing. Individual participants could appear in multiple categories, and their figured worlds grow and change as they navigate these tensions and their specific professional contexts and goals.

For Improvers, the DBER figured the world is a tool to improve an aspect of their current job: classroom, department or service work. It is an opportunity to self-reflect on their teaching and grow as professionals. However, their DBER figured world is challenged by the perceived need from the DBER community for extensive training and collaborations with established researchers in education research and the lack of departmental and/or institutional support. These tensions are shaping their transition into DBER, which illustrates the need for discussions and support structures in addressing this navigation that centers around changes and transitions in professional identity.

For Joiners, the DBER figured world is imagined to be a new primary research field. They are energized by the opportunity to explore the interdisciplinary nature of DBER and engage in applied DBER research. Encouraged by support from their institution and the DBER community, the multiple possible lens to approach research problems in DBER drawing from many fields: psychology, education, STEM disciplines creates excitement. They see

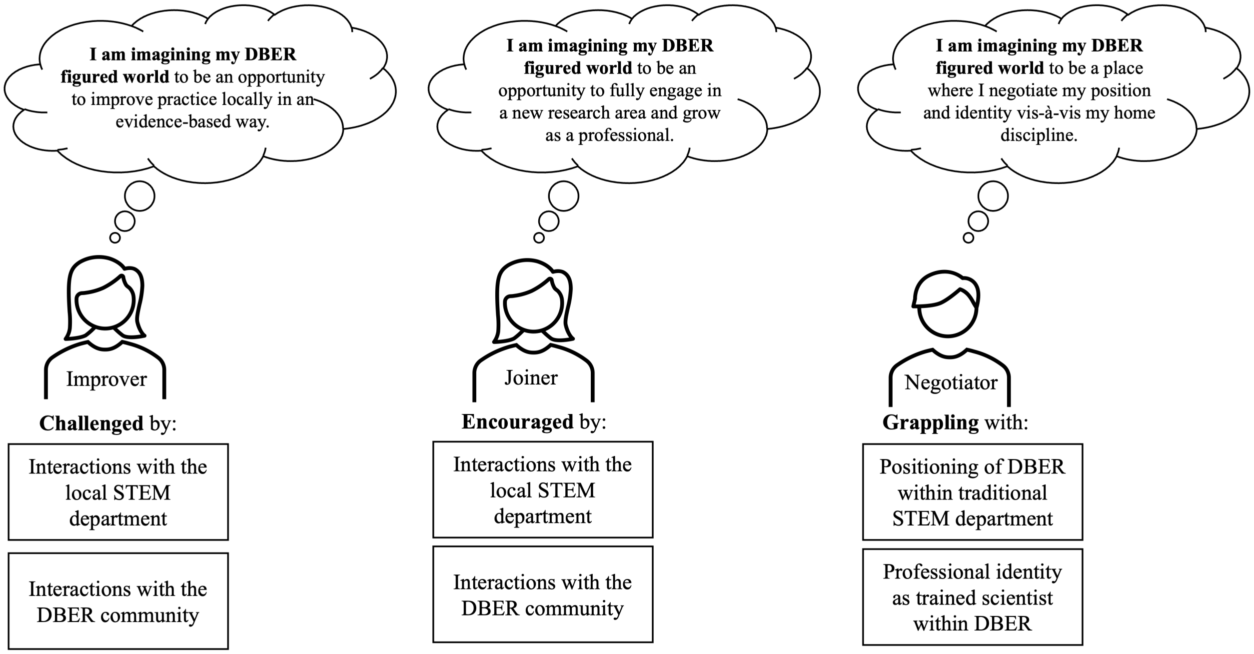

Figure 4.2: *Emerging STEM education researchers' conceptualization of their DBER figured world*

value and meaning in purposefully aligning their research on instructional change to their classroom practice to improve student experiences in STEM.

For Negotiators, their negotiations highlight different aspects of DBER as a figured world. Negotiating positioning in the DBER community foregrounds the collaborative and interdisciplinary nature of DBER while worrying about how expertise is valued within that community. In contrast, negotiating identity focuses on individual emerging discipline-based education researchers and how new research identities might be taken up. Finally, Negotiators who focus on the tension between education research and practitioner expertise are concerned that joining DBER might obligate them to fight cultural battles they do not yet understand; their figured world includes strife with powerful senior faculty.

The major difference between Improvers and Negotiators lies in where they are at in their conception of their DBER figured world. Improvers imagine DBER as a tool to improve existing responsibilities and the challenges and hurdles they face in their navigation of DBER, whereas Negotiators are imagining the possible tensions as they grapple with whether they want to use DBER for improvement of current responsibilities or joining a new research community.

Despite the nuanced difference between these two categories, Improvers and Negotiators face similar challenges in terms of imagining and identifying their position within the DBER-figured world. They are grappling with how to position themselves as trained scientists in DBER and how to manage existing tensions between DBER with traditional STEM disciplines. This significant correspondence between the challenges of Improvers and Negotiators as they conceptualize their DBER figured world suggests that DBER is hard to engage with because of two simultaneous challenging perceptions that newcomers have: the perception of legitimacy of DBER within local traditional STEM department and gatekeeping by the broader DBER enterprise. The latter is concurrent with findings from other researchers exploring emerging STEM education researchers' sense of belonging[89].

Comparing Improvers and Joiners, we notice that the similarity between these two categories lies within the fact they have a robust conceptualization of what their DBER figured world is. For Improvers, it is a tool to achieve in a research-based way their current needs as faculty, while for Joiners, it is a new area of research to fully engage to expand their research portfolio.

A notable distinction between Joiners and Improvers is their perceived contradiction of DBER as a result of their interactions or lack thereof with the DBER community. On the one hand, some emerging STEM education researchers perceive interactions with the broader DBER as encouraging them to engage in this research field. On the other hand, some emerging STEM education researchers have the exact opposite experience where their training and background in traditional STEM disciplines influences their interactions or lack of interactions with the DBER community, which fuels their sense of low-self-efficacy and low sense of belonging. This DBER dichotomy is an interesting reflection of how the DBER community is perceived by newcomers because it suggests that DBER is not unified in how it defines what it takes to do DBER.

When comparing Joiners and Negotiators, we notice the same two dichotomies we identified with Improvers and Joiners: the DBER dichotomy and the STEM department dichotomy. On the one hand, Joiners are encouraged by the ease of finding collaborations within the welcoming DBER community and the support of their departments and institutions to engage in DBER. On the other hand, Negotiators do not know yet how to figure our the norms of collaboration within DBER and how to navigate the boundaries between education research and practitioner expertise within STEM departments.

Looking across the three categories Improvers, Joiners, and Negotiators, we notice that a consequential entity in shaping emerging STEM education researchers is the local STEM department. Joiners engaging in action-oriented DBER in a supportive institution are encouraged to expand their research identity into DBER, whereas Improvers and Negotiations are navigating challenges involving the perception of doing education research in a traditional STEM department. Improvers who are doing service work and education research are pursuing their DBER work despite the challenge, whereas Negotiators are struggling to know what to do as they navigate this new uncharted territory for them, especially how to imagine their DBER figured world.

These dichotomies we see across categories are also reflected in our characterization of interview transcripts: half of our quotes from participants were coded within the Joiners category and the other half were coded within the Negotiators or Improvers categories. The data shows a clear split between those who want to join the DBER enterprise as a new research area to engage in as a community and activity and those who want to join DBER enterprise as a means to improve existing job responsibilities and/or negotiating the role of DBER for them.

Lastly, these findings about emerging STEM education researchers' conceptualization of DBER align with studies in higher education that investigate academics' understanding of research[85]. In particular, a phenomenographic study by Åkerlind identified four ways a university researcher conceptualizes being a researcher, which were "fulfilling academic requirements with research experienced as an academic duty, establishing oneself in the field with research experienced as a personal achievement, developing oneself personally with research experienced as a route to personal understanding and enabling broader change with research experienced as an impetus for change to benefit the larger community"[85]. Despite the different lens and dataset Åkerlind had in their study, the parallels between our

Improvers, Joiners and Negotiators conception of being a DBER researcher and the broader conception of being a researcher by academics are evident. The resemblances are intrinsically linked to being a researcher at institutions of higher education. Nevertheless, our dataset, which brings to the forefront STEM faculty's perceptions of research during their transition to DBER, is distinct from existing literature. Specifically, our findings highlight nuances in challenges and opportunities that are unique to academics in STEM disciplines such as the special relationship between disciplinary science and education research.

4.6 Implications

Awareness of the spectrum of ways emerging STEM education researchers conceptualize the DBER figured worlds provides the DBER community with knowledge of the perceived culture of the field to newcomers:

- There is a special relationship between disciplinary science and education research as interest in DBER stems for many discipline faculty from their teaching experience in their specific STEM departments and the priorities and challenges facing the department;
- The interdisciplinary nature of DBER across STEM fields is a special feature of DBER that emerging STEM education researchers grapple with, which highlights challenges academics may face navigating research areas outside their PhD or postdoctoral training in associating themselves with new disciplines.

Using the components of the figured worlds framework (recruitment and development, meaning creation, social organization and positioning) brings to the surface the underlying ideas and conceptions that emerging STEM education researchers may have about DBER. This opportunity to elicit the perceptions and challenges showcased how the role of the local STEM department is critical in emerging STEM education researchers' ability to imagine themselves in DBER. Our analysis also demonstarted how there is implicit messaging about who does and can do DBER that stems from emerging STEM education researchers' interactions with the broader DBER community that either encourages or discourages STEM faculty from doing DBER, suggesting the existence of conflicting values within the field.

To help build capacity and welcome new researchers to the field, support for the variation of DBER figured worlds of emerging STEM education researchers can help create a smoother transition for all.

For Improvers, the DBER community needs to consider the ways it can support emerging STEM education researchers within their local department and within the DBER community. First to support Improvers, we can continue to advocate for the value of STEM education research within disciplinary departments. For instance, PER physicists within physics departments bring knowledge about physics concepts, norms and training as well as expertise of education theories and methods that helps create content and context-specific research, which means "one of the strengths of PER is that it is not simply traditional education research conducted by individuals with a strong subject matter background, but rather it is a unique enterprise in which the techniques are strongly colored by the discipline in which it is embedded"[93]. Second, to support Improvers, we can more explicitly articulate the values of DBER, an initiative the STEM DBER alliance laid out a few years ago, which includes working across individual STEM disciplines to present a unified message to individual disciplinary societies and funding agencies of what DBER is and does[7].

For Joiners, continued support from their local institutions could include encouraging interdisciplinary partnerships across local STEM departments to sustain emerging STEM education researchers engagement and excitement about DBER. This interdisciplinary partnership aligns with the hopes, benefits and goals of the STEM DBER alliance, which encourages interactions across individual DBER fields[7]. For example, these partnerships could mean developing understanding of other context such as physicists developing an understanding of health sciences to create physics courses to health sciences majors and/or setting norms about DBER collectively as a result of interdisciplinary STEM research to foster the development of STEM education[7].

For Negotiators, support could include explicit discussions on the dilemnas and ideas they are considering in order to help researchers imagine or identify their figured worlds as they see fit within their specific socio-cultural contexts. Having explicit discussions about these challenges during professional development activities is an opportunity to support new scholars in the field of education research. For example, as our analysis in chapter 3 showed interactions with facilitator and interactions with participants in range of career stages during PEER helped participants' trajectory into DBER. Hence, helping emerging STEM education researchers understand and manage the tensions between DBER and home fields of research can help promote persistence and strengthen ties.

In summary, nuanced support structures across figured worlds based on category type can help researchers have a smoother transition to DBER, which can help build capacity in STEM education research.

4.7 Limitations

By using figured worlds to understand the experiences of emerging STEM education researchers, we centralized our analysis on how people negotiate their DBER engagement. However, figured worlds are constantly evolving as participants grow and engage within this space. As such it would be fruitful to explore how these emerging STEM education researchers continue to engage with DBER and how their figured worlds will change through their participation.

Figured worlds inform us what participants think of and imagine what DBER is and what the culture is. However, to better understand the DBER culture, we would need more data that includes the perspectives of established DBER culture in order to compare emerging STEM education researchers DBER figured world with established researchers DBER figured worlds to strengthen the perception of practices and norms at play in DBER.

Figured worlds allowed us to capture emerging STEM education researchers' challenges and identify areas where support is needed. The affordances identified in the data offered insights on what could perhaps be the focus and starting point of where support is needed. However, our figured worlds' analysis does not inform us in a practical way, how we could develop resources, and how to inform departments and institutions to better support their emerging STEM education researchers.

Lastly, not all STEM disciplines are captured in this dataset and all participants were already interested in engaging in STEM education research because many participants had already started their transition to STEM education research or were engaging in a program designed to help them jump start their transition in this new field of research for them. Future work should include other STEM disciplines and more potential emerging STEM education researchers to see if we missed any nuances that could have been influenced by participation in this professional development or nuances originating from the STEM disciplines not represented in our current dataset.

4.8 Conclusion

In this chapter, we used figured worlds paired with phenonmeonagraphy on a new population and in a different context than previous research, which provides a new lens to study emerging STEM education researchers experiences. We identified the spectrum of experiences that allows emerging STEM education researchers to identify or imagine themselves in DBER: Improvers, Joiners or Negotiators. These categories offer the nuances of DBER figured worlds emerging STEM education researchers have, which was not captured in previous DBER literature. In addition to their perception of themselves in DBER, we highlighted their interpretation of challenges and opportunities they are encountering in their engagement in DBER. This highlighted the need for support structures and resources for emerging STEM education researchers that capture the various nuances of emerging STEM education researchers as they transition into an interdisciplinary research field that has close ties with disciplinary science and across STEM disciplines.

Chapter 5

Personas for supporting physicists' engagement in informal education

A subset of the work presented in this chapter was published in the 2022 Physics Education Research Conference Proceedings[94].

In this chapter, we address **RQ3**: what are the motivations and professional development needs of physicists who engage in informal physics? We begin by providing an overview of informal physics education research, the specific context in which this dissertation research project was conducted and the motivation to get a deeper understanding of the professional development needs of STEM professionals engaged in informal physics spaces. Then, we discuss how we determined existing and prospective interests, practices and professional development needs of practitioners and researchers in order to support and develop their engagement in informal science education.

Note on terminology:

- Informal physics education refers to activities and events centered on engagement with physics outside the formal classroom. As stated in the introduction (chapter 1), we refer to informal physics and public engagement interchangeably as informal physics activities play an important role in the public's general understanding of physics and science. Public engagement has been defined as encompassing "the myriad of ways in which the activity and benefits of higher education and research can be shared with the public. Engagement is by definition a two-way process, involving interaction and listening, with the goal of generating mutual benefit" [95] .

- Many types of activities, platforms and programs fall under informal physics education such as after-school programs, public talks, demonstration presentations, open houses, science festivals, planetariums, social media, websites, popularized books, movies and games[96]. Despite the wide variety of possible activities, a common characteristic they share is that participation is voluntary and activities are meant to provide participants the freedom to explore and be curious about how the world works. We provide definitions of which activities our participants engaged with in section 5.4.1.

- Typically, "facilitator" refers to a physicist who either individually or with collaborators engages directly with the audience in informal physics spaces. "Practitioner" refers to a physicist who is involved in designing and managing an informal physics space; they may or may not also act as facilitators in the space. For simplicity, we will use the terms facilitator and practitioner interchangeably.

5.1 Informal Physics Education Research

Research in informal physics, often referred to as IPER, has focused on physics identity development, development of informal education programs, skill development for facilitators, impact of engagement in informal physics on audiences and the landscape of practices undertaken in this space.

The impact of informal physics engagement on developing the next generation of physicists and physicists enthusiasts is significant. Research shows that participation in informal physics programs enhances facilitators' communication skills, teamwork capacity and confidence significantly[97–99]. Moreover, participation in these programs has the added benefit of increasing sense of belonging to the field of physics for both facilitators and audience. In particular, for individuals from underrepresented populations, engagement with physics in these informal spaces allows them to develop their physics identity as they bring their whole selves to these spaces[6;99–103]. In turn, informal physics increases the interest and relevance of physics and science as a potential career path[104].

Furthermore, informal education programs provide opportunities for significant numbers of individuals in various geographic locations and diverse demographics to hear and engage with physics and physicists[105]. The dimensions at play in informal physics programs are varied, rich and nuanced. Izadi *et al.* provide an overview of all possible components in this landscape: personnel (volunteers and paid staff), resources (funding and community partners), program (goals, interactive activities and physics content), audience (geographic location and attendee demographics), assessment (educational research, tools and instruments for evaluation), institution (role of institution administration and type of host institution)[105]. These various dimensions provide many opportunities and avenues to engage with the public about physics. Hence, informal physics spaces can provide a direct and human face to science, which can increase the public's understanding, trust and confidence in the scientific process[106].

Efforts have also been made to survey programs to characterize some of the challenges faced in this space[107;108]. Factors such as personnel and funding were among the biggest barriers to the functionality and sustainability of programs long-term[107;108]. Additionally, there is a common sense of isolation for facilitators and researchers in informal physics education who struggle to sustain and grow their efforts in informal spaces[109;110]. Nevertheless, research remains scarce on the needs of facilitators of informal physics activities. Given that there is little research on what type of training and support these practitioners and researchers need in order to sustain, grow and feel connected to a community of informal science educators, there is a need to better understand the experiences of the physicists who facilitate these informal activities.

As a consequence, the central professional organization in the field of physics, the American Physical Society (APS)[111], has implemented initiatives and programs to engage the physics community in public engagement[24]. APS creates and invests in initiatives and programs in different professional development areas (education, diversity and inclusion, innovation, careers, and public engagement). Of most relevance to this dissertation is public engagement, which is the unit that creates programs and professional development to support physics learning outside the traditional formal classroom. The Public Engagement unit aims to support and empower the physics community to promote access and widespread participation in physics. In the first half of 2022, APS Public Engagement aimed to gather members' needs and interests around public engagement in order to develop an initiative named The Joint Network for Informal Physics Education and Research (JNIPER)[112].

5.1.1 Joint Network for Informal Physics Education and Research

JNIPER brings together physicists who facilitate informal physics learning activities, along with researchers who investigate the impact of these activities, to align and centralize the informal learning efforts of the physics community at large[112]. JNIPER aims to contribute to broad success of informal physics programs by creating a centralized community that meets three major goals:

1. Create a supportive, foundational community that connects groups of researchers and practitioners of informal physics education[113];
2. Facilitate research-practice partnerships to advance knowledge within the physics education research community[113];
3. Support adoption of research-based informal physics education best practices[113].

The long-term vision of JNIPER is to elevate the value and recognition for public engagement in physics. The network seeks to broaden participation in physics by fostering public engagement programs that are grounded in research and cultural competency, and oriented towards equity[113]. The leadership team behind JNIPER project defines culturally-competent practices in informal physics programs as practices that are knowledgeable of and responsive to the values, desires and practices of the community they are engaged with[113;114]. Equity-oriented practices are practices that ensure everyone has the same opportunities to engage in the environment considering privileges and power dynamics at play[115].The mission of the JNIPER initiative is to empower and support informal physics practitioners and researchers to enact these best practices.

However, since the pathways and engagement of physicists in informal physics education are varied, the dissertation author, alongside APS Head of Public Engagement (Claudia Fracchiolla) and APS Public Engagement Programs Manager (Alexandra Lau), developed a research project to understand physicists' needs around public engagement by leveraging APS membership network. Guided by the goal to design research-based useful programming and answer our research question: **What are the motivations and professional development needs of physicists who engage in informal physics?**, we conducted interviews with physics practitioners and researchers with a range of different experiences to design useful and targeted resources for stakeholders.

5.2 Methodology: Personas

Because we were trying to understand what are interests, needs, and challenges of APS members to do Public Engagement, we used a user-centered design methodology: personas. We use personas methodology because of its usefulness showcased in education research for instructional design and professional development. For example, the research team at PhysPort[116], a professional development website for physics faculty, used personas to improve the design and development of resources and activities for faculty by understanding their needs when making changes to their teaching[117]. Personas has also been used for undergraduate researchers to support the design of research programs with student-centered approaches based on their various motivations and experiences[83]. Additionally, personas has been applied to design instructional resources around learners' needs in the workplace[118].

Personas are person-like constructs created from data of a group of potential users, which are synthesized into archetypes[83]. Each persona is created around a common user's goal that stems from the data and informs the design process. Data from multiple individuals are abstracted into one persona. Users can identify with multiple personas depending on their motivations, needs, and context. Personas allow us to create targeted professional development resources based on motivations, needs, and experiences of potential users because they highlight the diversity of potential target users.

By creating archetypes that are very human-like without representing the peculiarities of one person, several benefits emerge. First, researchers preserve anonymity of interview subjects because the synthesized patterns are a combination of features from multiple interview participants[117]. Second, although some fictional details are added to personas to make them more human-like, personas represent real users for which resources are meant to be created instead of the assumptions of designers who may envision a variety of resources that are not useful for the actual target population[119]. Lastly, researchers focus on goals and needs of users in the entire design process of resources, which creates rich descriptions of a variety of experiences and needs of the target users. These benefits align with the goal of this project, which is to understand the needs of informal physics facilitators and develop user-centric resources to support them in order to lower barriers for implementation and participation.

5.3 Framework: Self-Determination Theory

We use Self-Determination Theory (SDT)[54] as presented in chapter 3 to inform personas development as it allows us to hone in on individual motivation[120]. SDT and personas methodology have been used together to identify research participants' various goals and motivations in previous physics education research work[120]. Since our unit of interest in this study are individuals who have the opportunity to grow professionally, we deliberately choose SDT to investigate the motivation of physicists engaged in informal physics, centering around their agency in making choices to reach their goals. Additionally, literature on informal physics education research supports this idea of intrinsic motivation being a driving factor for engagement in informal physics for both facilitators and participants[100]. In a study on physics students' motivations and experiences in informal physics programs, continued participation was determined to be driven by intrinsic reasons[100]. As explained in chapter 3, SDT suggests that three psychological needs: competence, relatedness and autonomy have to be satisfied to have the most self-determined form of motivation[55]. We contextualized the definitions of the components to be applicable to the informal physics context as follows:

- Autonomy: Desire to have sense of choice in their public engagement work;
- Relatedness: Desire to be connected and recognized with others in public engagement;
- Competence: Desire to experience mastery in public engagement work.

5.4 Methods

5.4.1 Context: Recruitment of Research Participants

To identify individuals and networks engaged in informal physics to participate in our study, we used a snowball approach[121]. We gathered an initial list of names and networks to tap into from researchers and practitioners in informal physics who engage with the American Physical Society (APS) public engagement efforts. Once we gathered a list of about 30 individuals, we sent out a screening questionnaire to ask if they were willing to participate in the research study and/or if they had suggestions for other individuals to seek out to broaden the network of practitioners and researchers engaged in informal physics education. For those who responded positively to the screening survey, we then reached out to conduct one-on-one semi-structured interviews for our research study.

Our data set contained 23 participants from various backgrounds and experiences in informal physics listed in Table 5.1. Interviews were conducted with practitioners and/or researchers who are engaged in informal physics activities, events and programs. Interviewees covered a large span of career stages: graduate students, post-doctoral researchers, physics teachers, physics faculty, physicists at national or international labs, and science communicator professionals. The type of activities they engaged in included working with groups at the universities, local schools, and a variety of public forums. We used the following definitions from the literature and participants' descriptions of the events and programs they engaged with to characterize they type of activities they engaged in:

- Public lectures are "talks that may be part of a lecture series and can be pitched at different levels. For example, weekend talks for high school students or nighttime talks for adults at local bars"[105];

- Demos are "presentations that provide information and illustrate how some physics concepts work through a series of demonstrations, which may involve crowd participation"[105];

- After school programs are "programs that provide activities and illustrate physics concepts for K-12 students outside of school time. They can be held at community, school or sometimes university campus locations"[105];

- Science museums events are presentations held at planetariums and museums for general audience;

- Recorded channels are features on podcasts, radio shows and news outlets.

Given the large landscape of possible activities in informal physics they engaged in, the audience they engaged covered the general public and/or student populations (K-12 and college students).

5.4.2 Data Collection

The semi-structured interview protocol covered four main topics: (a) the interviewee's current role and experience with informal physics; (b) their conception of and motivation for informal physics work; (c) needs with informal physics work; and (d) professional identity. Our protocol included questions such as: Could you give us a broad overview of your current professional obligations and involvement in public engagement? What is your current informal physics education/research community? What are some challenges/barriers you are encountering with engaging in public engagement activities? What would you need to overcome those challenges? What kind of support would be most helpful to you? The complete interview protocol can be found in Appendix D. Two versions of the semi-structured

Table 5.1: *Research participants' position, activity format, and audience of informal physics' engagement (*participant is an IPER researcher)*

Pseudonym	Pronouns	Position	Format	Audience
Charlie	They/them	Graduate student	Demos	K-12 students
Gabriella	She/her	Graduate student	After school program Science museums events	K-12 students General public
Abby	She/her	Graduate student	Demos	K-12 students General public
Liam	He/him	Graduate student	After school program	K-12 students
Anna	She/her	Graduate student	After school program	K-12 students
Carla*	She/her	Graduate student	After school program	K-12 students
Mia	She/her	Post-doc	After school program	K-12 students
Emma	She/her	High school physics teacher	After school program	K-12 students
Dylan	He/him	Physicist at national lab	Public lectures Recorded channels	K-12 students General public
Adam	He/him	Physicist international lab	Public lectures Recorded channels	General public
Lucy	She/her	Physicist at national lab	Public lectures Demos	General public
Dana	She/her	Physics faculty	After school program Demos	General public
Austin	He/him	Physics faculty	Public lectures	College students General public
Hailey*	She/her	Physics faculty	After school program	K-12 students College students
Felix	He/him	Physics faculty	Demos	General public
Paige	She/her	Physics faculty	Public lectures Science museums	K-12 students General public
Natalia	She/her	Physics faculty	After school program Public lectures	K-12 students General public
Lucas	He/him	Physics faculty	Demos	General public
Max	He/him	Physics faculty	After school program Recorded channels	K-12 students General public
Daisy	She/her	Science communicator	Public lectures	General public
Hannah	She/her	Science communicator	Public lectures	General public
Victoria	She/her	Science communicator	Public lectures Science museum events	General public
John	He/him	Science communicator	Public lectures Science museum events	General public

interview protocols were created to accommodate research participants' time availability. One was for an hour long interview and the other was for a thirty minute interview. Interviews were conducted by the dissertation author over video conference (Zoom), recorded, and transcribed (Zoom transcription service) for analysis. The length of the interviews varied between 30 to 60 minutes depending on the availability of the interviewee and how much detail the interviewee gave in their answers.

5.5 Personas Development

We conducted a thematic analysis[122]. The process consisted of reading the transcripts and paying particular attention to the participants' answers about goals, needs, and resources for engaging in informal physics. For each transcript, key ideas of participants were identified and given a theme such as *interest in informal physics: recruiting underrepresented populations to physics*, *resource used: discussions with practitioners*, *challenge: isolated from community*, *need: science communication: meeting your audience where they are at*. All transcripts were read and an initial list of codes were generated.

Afterwards, we created a table summarizing the following information for each interview: career stage (physics graduate student, postdoc, faculty, informal physics professional, physicist at national laboratory, high school physics teacher), motivation to engage in informal physics, resources used, resources needed and challenges faced. Quotes illustrative of motivation to engage in informal physics were also included in the table.

5.5.1 First Iteration

In our first iteration of personas, we identified patterns in terms of goals, challenges and resources needed. This led to the creation of a list of potential archetypes distinct in their goals. The archetypes were an abstraction from the details of the individual interview participants. Overlapping patterns of challenges and resources needs emerged while creating these person-like constructed based on their motivations to engage in informal physics. Discussions occurred among the research team on how to resolve these overlapping patterns. We ended up going back to the data to identify challenges that were either unique to a persona and/or were the most prevalent challenge cited by interviewees that could identify with that persona. These prioritized challenges then corresponded directly to the resources needed that people talked about. The process of personas development in this first iteration is illustrated in Figure 5.1.

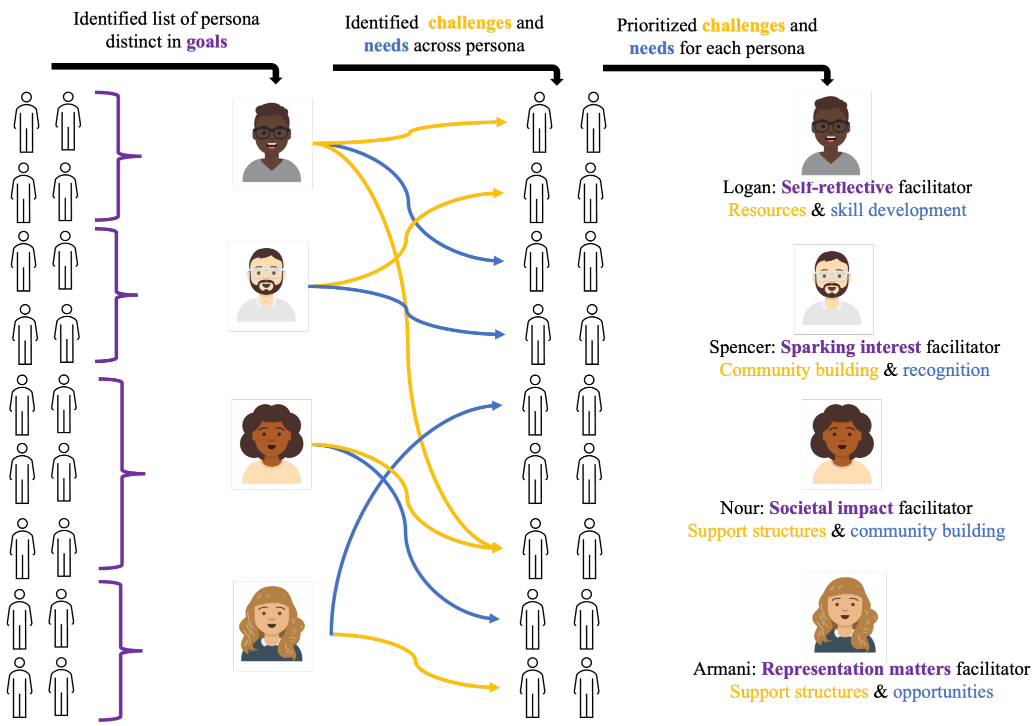

Figure 5.1: *Process of personas development in the first iteration: the stick figures represent interview participants, the characters represent the personas, goals are colored in purple, the yellow arrows and text represent challenges and the blue arrows and text represent needs*

Our first iteration underlined the nuances in needs from a wide range of practitioners' experiences, which led to the creation of four personas: Logan, Spencer, Armani, and Nour. However, the limitations we faced with the overlap in the challenges and needs across most stakeholders made it challenging to create distinct personas. For example, a common theme that emerged was the need for recognition, but there were some nuances. Some users wanted recognition from those in higher positions of power at their organization and some wanted recognition from the entire physics community. Some proposed various ways by which this need could be addressed, such as national awards from professional societies for their work in informal physics to elevate its status in the physics community. We also noticed that the character of the goals of two of the personas, Spencer and Nour had significant overlap, but simple pattern recognition did not provide us with a way to untangle the nuances. Therefore, we made deliberate choices to prioritize needs based on what challenges were unique and/ or appeared most frequently around each motivation, and what we could practically implement in our design process. Given the limitations of this first iteration, we went through another round of personas development grounded in motivation theory.

5.5.2 Second Iteration

Starting from the table summarizing information for each interview created from thematic analysis, in our second iteration of personas development, we used the components of Self-Determination Theory to differentiate the goals individuals may have.

Using the SDT components (competence, autonomy, and relatedness), we reclassified participants. We identified distinct patterns in terms of motivation and resources. This led to a clearer list of archetypes, where all goals fell in the relatedness category but with different nuances. Then we characterized, using the SDT components, their reasons for stating a need for specific professional development resources. For example, users motivated by the opportunity to self-reflect on their journey and relate their growth to the public often expressed needs for resources around increasing their competence and mastery of their public engagement work, through skill development of varying degrees. This feature allowed us to address the limitation of the first iteration and create a set of personas distinct in their goals and needs thanks to the framing offered by the theoretical components. These nuances of needs also allowed us to brainstorm ways to address to best support our goal of designing user-centered resources. We listed in Table 5.2 potential resources to directly address participants' needs.

In addition, for each persona created in this iteration, an example case of a particular human was created to provide more context to the reader of background, activities and audience in informal physics. The example created for each persona was drawn from the interview participants description of their activities and engagement, but we did not create the example from one particular participant as to preserve the anonymity of the participants and remain consistent with personas methodology. Lastly, discussions occurred among the research team on the personas created to refine their development until consensus developed among the project's researchers.

5.5.3 Personas Iteration Refinement Discussion

Our second iteration of personas allowed us to be more theory-driven in creating distinct personas. The benefits were two-fold.

First, we had personas motivated by nuanced variations of relatedness, highlighting the consequential role of relatedness in motivating engagement in informal physics. Relatedness as a critical mechanism that drives engagement in informal physics is not surprising as it is inherently a two-way interaction activity.

Second, we had less overlap in needs when characterizing stakeholders with the SDT components. One component (relatedness, autonomy or competence) appeared most frequently around needs associated with each motivation, which facilitated the needs characterization in the development of personas. Moreover, the second iteration allowed us to provide a more concrete example of what that persona looked like based on our users and the character of their needs identified.

Structurally, we went from four personas to three more distinct personas. As seen in Figure 5.2, the second iteration analysis combined Spencer and Nour into one persona, Rory. In particular, the motivation theory elucidated how the character of the motivation of Spencer and Nour were two sides of the same coin: sparking interest and understanding of physics leads to societal impact. Additionally, for Logan and Armani, the motivation theory allowed us to articulate in a more robust way the justification for Logan's internal self-reflection and Armani's equity lens. The nuanced differences that the motivational theory provided also translated to subtle nuances in challenges and needs, which we detail in the

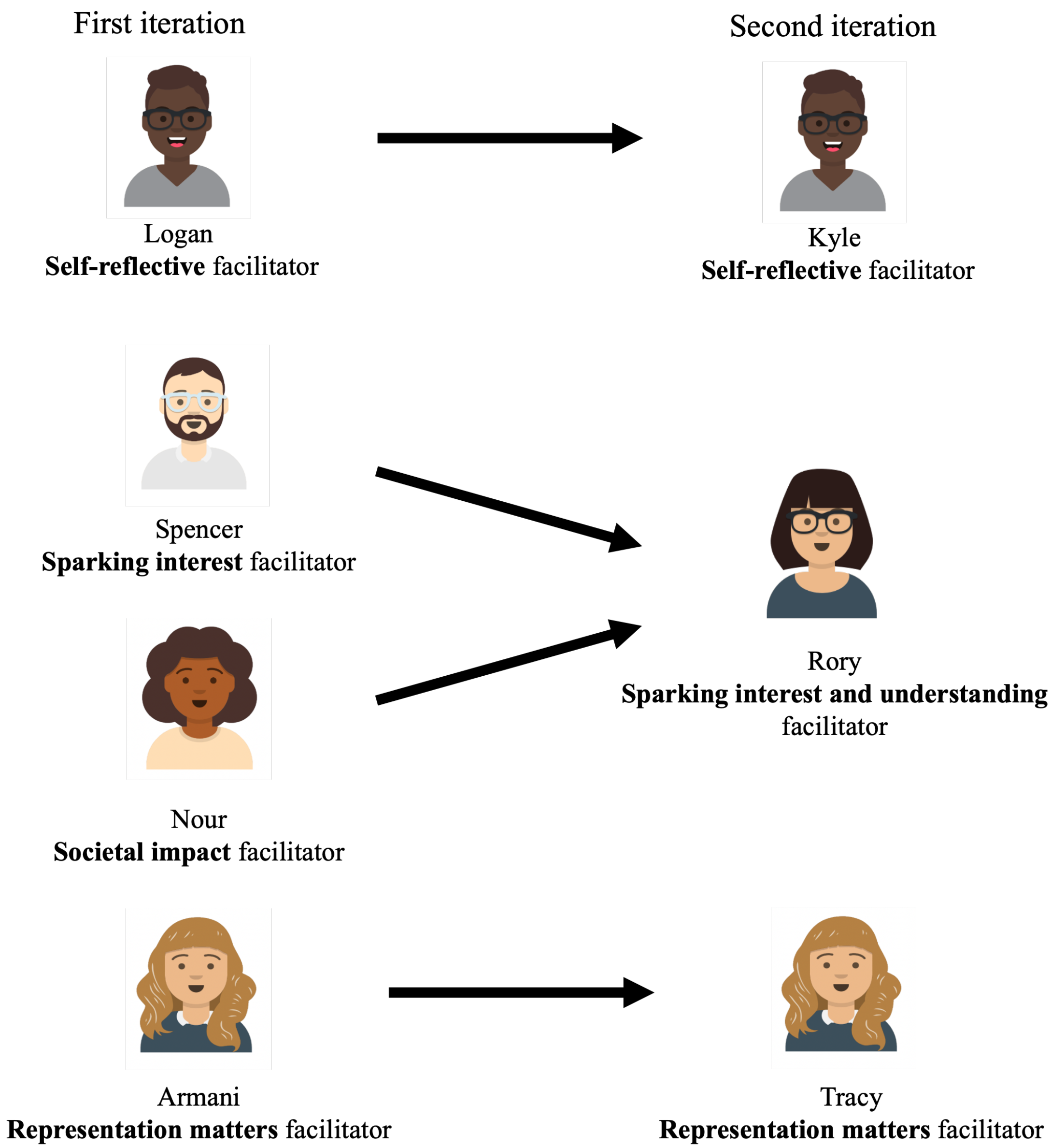

Figure 5.2: *Personas iterations: refinement included motivation theory enabling us to go from four personas in the first iteration to three more distinct personas in the second iteration.*

findings and discussion sections. Nevertheless, in our second iteration, the label of each persona remained the same, but we changed the nickname associated with each persona to reflect the nuance gained between the first and second iteration as the theory allowed us to differentiate, articulate and interpret the users' needs more clearly.

5.6 Findings

We present our set of three personas: Kyle, Rory and Tracy. They stem from our two iterations of personas construction from our data set.

Kyle, the self-reflective facilitator, engages in informal physics because they enjoy how energized they get when interacting with an audience to convey knowledge. It is an opportunity to self-reflect on their experience in physics (their belonging and own understanding of content knowledge in physics), which allows them to relate their journey with their audience. A representative quote of Kyle's goal is:

> *I personally get a little bit of a high from doing it. I love to be in front of a crowd and talking about things that I know. I love answering people's questions.*

Although engaging with the public energizes Kyle about their science and enables self-reflection, they find it challenging to figure out how to interact with different types of audiences. They are also facing organizational challenges. They are not sure how to best organize their engagement in informal physics to sustain their engagement for long periods of time while managing their many responsibilities. Kyle expressed needs around competence, the desire to be better at informal physics. They would like to have access to centralized resources on how to get started when engaging with a specific type of audience or event in informal physics. They also would like to get training in science communication to best engage with different types of audiences and develop their skills in designing, managing and organizing activities and events with multiple stakeholders (volunteers, audience, institutions).

An example of Kyle would be a physics graduate student who is part of a student-led program that works with K-12 students during an after school program. They work to provide activities and illustrate physics concepts sometimes at the school or sometimes on university campus locations.

Rory, the sparking interest and understanding facilitator, engages in informal physics because they enjoy conveying their excitement about science to others and seeing the "light bulb" moments when participants understand a new physics concept. This motivation is driven by their desire to connect scientists and the public to form better relations and understanding of the scientific process. A representative quote of Rory's goal is:

> *I love when students figure something out and they get super excited and start explaining it to all their friends. [...] So the possibility that when I am doing one of these events that I could inspire someone to go to work in the sciences, positively be working in physics areas that I am really passionate about. They could go on to discover great things. As a by-product, my work in outreach and engagement is also about getting the audience to appreciate science so the scientific process has become much more of what I try to teach.*

As a by-product of sharing their excitement with their audience, Rory is not only hoping some participants may consider a STEM career path, but also appreciate the scientific process. Rory is developing as a facilitator through practice and trial and error. Their needs are centered around relatedness and connecting with the community, particularly being supported and engaged with a community of practitioners. They would like to bridge the following two gaps in order to expand their engagement with the broader physics community to elevate the value of public engagement:

- The gap between physicists who engage in informal physics and physicists who do not (e.g. connecting faculty who engage in informal physics activities part time and faculty who do not engage in informal physics at all);
- The gap between full time informal physics professionals and physicists who engage in informal physics part-time (e.g. connecting faculty who engage in informal physics activities part time and science communicator professionals who do it as a full time job).

An example of Rory would be a science communicator professional who works closely with the public engagement units in national or international labs. Rory talks with the public during guided tours of the lab and plans demos for specific events for students at the lab.

They also engage with the public on news outlets and radio shows about physics discovery, history or latest newsworthy research developments.

Tracy, the representation matters facilitator, engages in informal physics because of their identity connection with the audience. This motivation is driven by the value they see in inspiring diverse persons to pursue STEM careers paths. A representative quote of Tracy's goal is:

> *I'm trying to get more girls, women and people of color into physics.*

Tracy discusses their informal physics efforts with other practitioners but is frustrated by the pushback they receive from the scientific community, which does not always see it as an integral part of a physicist's job. To support their work in this space, they need resources to foster their autonomy in this space:

- Funding to allow them to recruit and retain more individuals in informal physics programs and expand assessment of programs and informal physics events;
- More buy-in from institutions on the value of their informal physics work, which would foster their sense of agency in what they can do in this space;
- Logistical and managerial support for their public engagement activities. They need an infrastructure to be built in order to foster their sense of autonomy. This will allow them to dedicate their time and efforts to the content and design of the engagement activities.

Tracy's motivation and needs are concurrent with findings from the literature, which has shown the critical role that recognition and relational resources play in linking programmatic efforts to support representation of students from underrepresented groups and student physics identity[123].

An example of Tracy would be a physics faculty who engages with the general public during public talks about their science. Tracy works with K-12 schools where they provide information and illustrate how some physics concepts work through a series of demonstrations.

We summarized Kyle, Rory and Tracy's key needs and implications for the development of resources in Table 5.2.

5.7 Discussion

We identified in our dataset three personas: the physicist who engages in informal physics for self-reflection, the physicist who wants to spark interest and understanding of physics, and the physicist who wants to provide diverse role models to younger students and inspire them to pursue a STEM career. Multiple iterations of personas development underscored the value of a motivation theory to differentiate goals to do informal physics and characterize distinctly the archetypes and various challenges and needs of our users. Using personas highlighted features of physicists' needs we may not have captured otherwise. For example, in constructing personas, we noticed that career stage and motivation are not in a one-to-one correspondence. There were multiple career stages represented in each persona. We had not expected that needs were not solely dependent on career level. This highlighted the value of using personas for a user-centric approach rather than researchers' assumptions about users' needs. This informed us that career stage may not be the best distinguishing factor, but motivation to engage in informal physics, which was further validating our personas methodology for this project.

By developing this set of personas, we are expanding on the informal physics community's understanding of the needs of practitioners in this space. The development of these three personas informs the design of resources listed in the third column of Table 5.2, created for JNIPER. In particular, this list of possible resources informed the first set of initiatives APS JNIPER program launched in Fall 2022, which includes monthly coffee hours and a JNIPER slack channel where members share resources. The coffee hours address Rory's need around community building, specifically the need of connecting several types of professionals in the informal physics space. The coffee hours also address Tracy's need to have discussion spaces to advocate for the needs of informal physics facilitators' autonomy. Furthermore, the active online community is a first step in addressing Kyle's need of having a resource hub on how

Table 5.2: *Personas representing variation of physicists around needs in informal physics and potential implications research team designing resources.*

Persona	Key needs	Implication for designing resources
 Kyle: the self-reflective facilitator	To support competence development, they need: • A centralized resource hub to get started • Science communication training • Skill development on how to organize to sustain engagement in informal physics	• Designing a searchable list of activities that are easy to implement • Designing training on skill development: storytelling with confidence and logistical programmatic factors
 Rory: the sparking interest and understanding facilitator	To support relatedness, they need: • Community building among physicists • Community building between physicists and science communication professionals	• Designing opportunities to share ideas and findings with other practitioners, professionals, researchers at conferences • Designing a network that allows practitioners to identify opportunities to partner with other practitioners or with researchers
 Tracy: the representation matters facilitator	To support autonomy, they need: • Funding for informal physics • More buy-in from institutions • Investment in infrastructure to support informal physics	• Designing spaces for discussions to occur to get the community to recognize and elevate the value of informal physics • Designing opportunities to share benefits of public engagement and advocate for funding

to get started, share best practices and materials. As expected with personas methodology, a few activities can serve multiple user-types, even if the reason why the activity is helpful differs between each user. Hence, bringing this methodological approach to professional development in informal education enriches the development of user-centric resources to support informal physics facilitators.

5.8 Conclusion

Physicists engage with the public to varying degrees at different stages of their careers, but their public engagement covers many activities, events, and audiences, making their motivations and professional development needs not well understood. As part of these ongoing efforts to build and support community in the informal physics space, in this chapter, we discussed the findings from our interviews with physics practitioners and researchers with a range of different experiences to design useful and targeted resources for stakeholders. We discussed our successive iterations of how we determined existing interest and professional development motivations and needs of practitioners and researchers in this space. The development of the three personas brings user-centered design to informal physics professional development research and broadens our understanding of motivations and needs of physicists engaged in science outside the formal classroom.

Chapter 6

Conclusion

In support of current trends to broaden participation in STEM by building STEM education and research capacity[1], this dissertation examined the development of a national sample of STEM professionals: those who take up education research later in their career, those looking to use education research to strengthen their classroom presence and those who facilitate engagement in physics learning outside the formal classroom. In this chapter, we summarize the results and implications of this study as well as provide some potential future research directions to explore.

6.1 Findings & Implications

The research purpose of this study was to understand the ways in which the STEM community can best support the professional development of STEM professionals who integrate education research or public engagement in their professional endeavors. We examined how and why they navigate and conceptualize integrating new research fields areas as well as their experiences integrating informal physics in their careers through three different research questions.

6.1.1 Research Question 1

RQ1: How do emerging STEM education faculty gain agency during the process of engaging in discipline-based education research?

Using Bandura's agency framework, we did a multiple case study analysis of three participants in a professional development program, tracking how program activities affect their agency as researchers. We identified the elements of the professional development program that increased agency of our case study participants' trajectory in education research, which includes receiving information to get started, building mechanisms to sustain research projects and engaging with a supportive community. We also explored how addressing one or a combination of self-efficacy sources echoed into growth in other components of agency.

Our analysis of the first research question shows that professional development for faculty cannot just focus on particular skills development but needs to fully incorporate activities that have the potential to increase self-efficacy, which does not only include procedural knowledge workshops and feedback on project. It is also critical to build space for interactions with researchers in range of career stages and interactions with researchers with DBER expertise. Furthermore, when creating and building professional development workshops to build capacity in DBER, we need to intentionally center agency as a central tenet of these opportunities as it can have positive impact on researchers at every career stage and various types of departments and institutions.

6.1.2 Research Question 2

RQ2: What do emerging STEM education faculty currently perceive or imagine the role of discipline-based education research to be for them?

Grounded in Holland's figured worlds framework, we identified the spectrum of ways emerging STEM education researchers identify or imagine themselves in DBER: to improve their teaching, to make it their new primary research field, and to negotiate how this new research field will fit with their primary one. We highlighted salient negotiations they are encountering in their DBER engagement. In particular, we articulated two ways in which there is a special relationship between DBER and disciplinary science.

First, engagement in DBER often stems from experiences as discipline faculty, which highlights the challenges of navigating in research areas outside their PhD or postdoctoral training in which their academic identity is formed. As STEM faculty become education researchers, they are not only navigating a new research field, they are also trying to see how it fits within the local needs of their department and institution. Thus, attending explicitly to each participant's institution type, department priorities, and career stage is important to help them be successful in their research endeavors.

Second, the interdisciplinary nature of DBER that spans beyond discipline expertise, yet is rooted in particular conceptions of knowledge and norms found in STEM disciplines, creates a blend of norms and ways of doing in DBER that is perceived as both appealing and daunting to emerging STEM education researchers. As such, the DBER community should attend to both of these viewpoints. This can include the DBER community encouraging more collaborations and partnerships across STEM disciplines within the DBER landscape in order to more explicitly and collectively define what the norms of the field are.

6.1.3 Research Question 3

RQ3: What are the motivations and professional development needs of physicists who engage in informal physics?

Physicists engage with the public to varying degrees at different stages of their careers. However, their public engagement covers many activities, events, and audiences, making their motivations and professional development needs not well understood. To answer RQ3, we used self-determination theory and personas methodology to identify the motivations and needs of facilitators in informal physics. We discussed our process of development of three personas: the physicist who engages in informal physics for self-reflection, the physicist who wants to spark interest and improve the relationship between scientists and the public in physics, and the physicist who wants to provide diverse role models to younger students and inspire them to pursue a STEM career. These personas enabled the development of user-centered and targeted professional development resources initiated by the central professional society in the field of physics.

By developing this set of personas, we highlighted the nuanced variations in motivation and needs of practitioners in informal physics. Intrinsic motivation drives many physicists' engagement in informal spaces, however their needs span a large spectrum of characteristics from improving competence to fostering autonomy to connecting with various members in the community. Understanding this landscape of motivation and needs in informal physics broadens our understanding of why physicists engage in informal spaces. In particular, these personas showcase the fact that despite a similar source of intrinsic motivation, informal physics practitioners' needs vary and so must their professional development support. Designing resources that supports the variety of needs of practitioners has the added benefit of improving STEM education as engagement in informal physics translates to increase of sense of belonging in STEM[6] and increase understanding of science by the public[106].

Bringing personas methodology to the development of resources in informal physics helps educational developers design more targeted and inclusive resources by capturing the diversity of activities and experiences in this learning environment. Although the use of personas is not new to physics education research[83], applying this approach in a new topical area of physics education and to a different type of population within physics expands the methodological toolbox of informal physics education research. Thus, we open up the possibility to use design-based research in this topical area of physics education research.

6.1.4 Synthesis

Using agency, identity and motivation frameworks combined with qualitative research methodologies, we investigated three different ways STEM professionals continue to grow in their careers. As a consequence, we gained a deeper understanding of their professional development structure and needs. Although the type of activity they engaged in differed (education research and physics public engagement), our analysis captured the need for targeted and tailored programmatic support, which takes into account professionals' STEM discipline expertise and training, their particular career goals and the priorities in their department and institutions. Community support, both the local STEM department as well as the broader STEM enterprise, was emphasized and deemed critical in support of their professional development.

6.2 Future work

Future research could further expand the scope of the data to draw in additional nuances we may have missed or substantiate our findings.

In our study addressing **RQ1**, our exploratory analysis drew upon self-reported data of three faculty's experiences, which cannot be generalized to all emerging STEM education researchers. Future work should include other participants' experiences to explore contrasting experiences with agency growth, especially for STEM faculty at different career stages and types of institutions.

In our analysis of **RQ3**, we identified that professionals engaged in informal physics are intrinsically motivated to so despite the challenges they may face. Nevertheless, a common need that emerged was having informal physics being more recognized and building community. To better understand this need, it would be interesting to incorporate data from STEM professionals who chose to not participate in informal physics. Emergent patterns within this larger data set would allow us to better understand experiences of informal physics practitioners within the broader physics community.

Future research could investigate other types of transitions STEM professionals may encounter in their careers to identify the patterns and themes that emerge in career-long professional development endeavors.

One of the underexplored themes from our study of **RQ2** was that engaging in DBER is perceived as having a different character from other possible research transitions that are plausible within an academic's career. Thus, it would be insightful to contrast emerging STEM education researchers' experiences with other research transitions. For example, do researchers perceive, imagine and navigate their transition from physics to chemistry similarly or not? Is the transition from physics to physics education research akin to the transition from computer science to quantum information science? In others words, future work could investigate the development of STEM professionals when taking up other academic endeavors to better understand the peculiarities and/or transferability of integrating new endeavors within one's career.

Another theme that could be investigated as result of our analysis of **RQ2** was how graduate and/or post-doctoral training strongly impacts the self-efficacy of STEM researchers as they engage in new research areas throughout their academic career. Given that a significant number of PhDs and postdocs transition to industry research post-academic training[124], it would be interesting to investigate whether or not the character, challenges and opportunities STEM professionals face within academic research transitions is akin to professional endeavors out of academia. Drawing parallels between different types of STEM career endeavors could provide us with insights on the factors of STEM education training that shape STEM professionals' career trajectories.

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Appendix A

Interview Protocol about Experiences of Emerging STEM Education Researchers (Pre-PEER)

Set-up and Introduction

(Gallery view. Open up the Chat window, make it visible, and select Private Chat.)

“ Hi, I’m NAME. Thanks for taking the time to talk to us today! NOTE TAKER NAME is primarily going to be taking notes, and may chime in at the end with some questions if we have time.

Just to refresh your memory, the goal of this project is to understand how we can better support new and emerging discipline-based education researchers as they engage in the PEER (Professional-development for Emerging Education Researchers) workshops. We would like to better understand your motivations, needs and expectations in participating in the PEER program.

Before we begin, do you have any questions about the consent form?

With your permission we would like to record this interview to help us conduct more accurate data analysis. Can we record this interview?

(Make sure in Gallery view; Check that recording has started.)

Just to have your permission on the recording, do you agree to having us record this interview?

In order to protect your identity, we will use a pseudonym to refer to you during the study. Do you have a name that you would like us to use or would you prefer that we pick one? What pronouns would you like us to use for you?

As a reminder, participation in this interview is voluntary. You may decide not to participate at any time during the interview.

Great, thank you again!"

Interview Questions

Interest in PEER

1. What brings you to the PEER program?

   - Why did you apply to the PEER program? What drew you to participate in the upcoming PEER workshops?
   - To help us get a better understanding of your background, could you tell us a little about your current position.
     - Are you in physics or mathematics or . . . ?
     - What's the balance of teaching and research in your position?
     - How big is your department? Is it math/physics/education/something else?
     - Could you share your current obligations for research/scholarship, teaching, and service
   - What counts as research/scholarship for the purpose of your career advancement?
   - How does your current institution and department value discipline-based education research (DBER)?

Interest in DBER

We would like to discuss or elaborate on your interests in DBER.

- What is your background in DBER?
- Why are you interested in DBER?
- What is exciting about DBER?
- How does DBER fit in your future professional goals
- When you imagine doing that research, how do you imagine it?

Experience in DBER

Could you tell us about some of your experiences in DBER?

- You indicated that you had
  - some experience with DBER via [XXX]. Could you talk about your role in [XXX]? Tell us about that experience. What did you imagine would be the benefits going into this?

  or

  - minimal experience with DBER. You noticed a problem. How did you notice it? What prompted you to try to fix it? How do you envision conducting a research project around [activity]? What do you imagine would be the benefits going into this project?
- Have you attended any conferences or workshops?
- Have you presented your work?
- Have you written any papers?
- Are there any other DBER activities you have led or participated in that you haven't shared yet (grants, data collection, analysis, program evaluation, etc.)? Could you talk a bit about your role in [this activity]?
- What do you hope to accomplish with DBER?

Expectations from participation in PEER

1. What are your expectations? What do you hope to gain from your participation in the PEER program?
    - in a practical sense (create collaboration, find an advisor(s), develop a specific skill..)?
    - What does mentorship/collaboration look like for you?
    - on a personal development level (outlook/perception of DBER ...)? other factors/considerations?
2. What do you want PEER to look like for you?
    - What do you envision your experience at PEER to be like?
    - What kinds of things do you think you need to bring with you to be successful at PEER?
    - What do you hope you will take away at the end?

Perception of DBER

1. What is your current perception of the DBER field?
2. What is your current DBER community? What kind of support do you have for your DBER work (community, supportive colleagues/administrators, financial etc..)?
    - Who in your community do you talk to about your current or future research?
    - In what ways does your current community support your research goals?
    - Are there any other supports (e.g to materials, training etc) that would have been beneficial when you wanted to get started in DBER projects or when you faced challenges in DBER projects you've been part of?
    - Have you had interactions with the DBER community (conferences...)? What has this experience been like?

3. How do you describe your current professional identity? Do you describe yourself as a DBER researcher? Why or why not?

4. How do you relate different aspects of your professional identity to your DBER work? How do you feel DBER relates to your teaching?

5. What else would like us to know about you at this stage?

Wrap up

1. (At 50 min:) I'm mindful of your time; do you need to go right at (XX time)?

2. Before we close, is there anything you'd like to add or anything we should have asked you about, but didn't?

3. Are there any questions that you have for us?

"Thank you so much for your time! This was very useful and we really appreciate it."

Appendix B

Interview Protocol about Experiences of Emerging STEM Education Researchers (Post-PEER)

Set-up and Introduction

(Gallery view. Open up the Chat window, make it visible, and select Private Chat.)

"Hi, I'm NAME. Thanks for taking the time to talk to us today! NOTE TAKER NAME is primarily going to be taking notes, and may chime in at the end with some questions if we have time.

Just to refresh your memory, the goal of this project is to understand how we can better support new and emerging discipline-based education researchers as they engage in the PEER (Professional-development for Emerging Education Researchers) workshops. We would like to better understand where you are after participating in the PEER program.

Before we begin:

Do you have any questions about the consent form or this project?

With your permission we would like to record this interview to help us conduct more accurate data analysis. Can we record this interview?

(Make sure in Gallery view; Check that recording has started.)

Just to have your permission on the recording, do you agree to having us record this interview?

In order to protect your identity, we will use a pseudonym to refer to you during the study. Do you have a name that you would like us to use or would you prefer that we pick one? What pronouns would you like us to use for you?

As a reminder, participation in this interview is voluntary. You may decide not to participate at any time during the interview.

Great, thank you again!"

Background

For new interviewees:

1. Tell us a little about your current position.
    - Are you in physics or mathematics or ...?
    - What's the balance of teaching and research in your position?
    - How big is your department? Is it math/physics/education/something else?
2. Before PEER, what was your background in DBER?
3. How does your department treat DBER work for the purposes of tenure and promotion (faculty only)?
4. How much time could you have devoted to research last week?
5. Does your institution explicitly value external collaborations?

For re-interviewees, has anything changed since we talked last time?

1. How much time could you have devoted to research last week?
2. Does your institution explicitly value external collaborations?

Perception of PEER

1. How was PEER for you?

    - Did it live up to your expectations? Why or why not?
    - Was your PEER experience what you envisioned it to be like? How so?
    - What are some things you did not get at PEER but hoped you had?

2. What do you think you have gained (skills, people...) from your participation in the PEER program?

    - Were there particular workshops that were most impactful for you? Which ones? Why?
    - How do you know if you have gained (or not) these things?
    - How do you know if you have gained (or not) these things?
    - Were there topics you would've liked to see in more depth? Less depth?

3. People and collaboration

    - Did you meet new potential collaborators? How will you collaborate with them?
    - Mentors?
    - Mutual support peers
    - How do you plan to work with them in the future? Accountability groups, the slack, joint projects...
    - Are there other roles that you would like other people to fill?
    - How would you like to help with or contribute to your peers' projects?

4. Did you make significant progress in your thinking about your project?

    - Did you make significant progress in your thinking about your project?

5. What do you think PEER is now? What are some of your takeaways from your experience?

Experience in DBER

1. During PEER
   - What is your research project about?
   - How did your research project evolve during PEER? In what ways?
2. Present
   - Where are you currently at with your DBER research?
   - How do you feel about your work?
3. Future
   - What comes next for your research project?
   - What skills do you hope to develop in the future?
   - What are some of your goals for your research?
   - Do you feel like you have the skills to achieve your goals?
   - When you get stuck, where will you look for help?
   - How will you know you have gained these skills/accomplished goals?
   - Do you have plans to publish or present? Are DBER publications part of your tenure plans?

Perception of DBER

1. What is your current DBER community?
   - What kind of support do you have for your DBER work (community, supportive colleagues/administrators, financial etc..)?
   - What kind of support do you wish to have for your DBER work?
   - How has your DBER community expanded while you were at PEER? Have you gained new collaborators?Do you feel that you have gained mentors who you can reach out to and/or work with in the future?

- Are you planning to go to specific conferences in the near future (example: RUME)?

2. Before PEER, had you participated in a DBER conference or workshop?
3. Before PEER, had you experienced DBER people?
4. Before PEER, had you submitted a paper or poster in DBER?
5. And then what happened?
   - Was that a good experience for you?
   - What kinds of feedback did you get?
   - What have been your prior experiences with other DBER people?
   - Did you feel welcome? Did you feel like you could ask them basic questions?
   - Do you still work on that project?
6. How has your perception of the DBER field changed?
7. How has your understanding of DBER evolved with your participation in PEER?
8. What are some challenges you are encountering with the field?

Identity

1. How do you describe your current professional identity?Do you describe yourself as a DBER researcher? Why or why not?
2. How do you relate different aspects of your professional identity to your DBER work?
   - How do you feel DBER relates to your teaching?
   - Have your ideas about how DBER and your teaching interact changed during PEER?
   - How does being an instructor help you be a better DBER person? How does DBER help you be a better instructor? Is this important to you?

Wrap up

1. (At 50 min:) I'm mindful of your time; do you need to go right at (XX time)?
2. Before we close, is there anything you'd like to add or anything we should have asked you about, but didn't?
3. Are there any questions that you have for us?

"Thank you so much for your time! This was very useful and we really appreciate it."

Appendix C

Interview Protocol about Experiences of Emerging STEM Education Researchers (General)

Set-up and Introduction

(Gallery view. Open up the Chat window, make it visible, and select Private Chat.)

"Hi, I'm NAME. Thanks for taking the time to talk to us today! NOTE TAKER NAME is primarily going to be taking notes, and may chime in at the end with some questions if we have time.

Just to refresh your memory, the goal of this project is to understand how we can better support new and emerging STEM education researchers. We are interested in talking to you because you have had experience with STEM education research. We would like to understand your successes, challenges, motivations, and needs in doing STEM education research.

Before we begin:

(If consent form has been received) Thank you for sending us your interview consent form. Do you have any questions about the consent form or this project?

(If consent form has not been received) Have you seen the consent form attached in a recent email? (Help interviewee find and review consent form, sign consent form, and email you consent form.) Do you have any questions about the consent form or this project?

With your permission we would like to record this interview to help us conduct more accurate data analysis. Can we record this interview?

(Make sure in Gallery view; Check that recording has started.)

Just to have your permission on the recording, do you agree to having us record this interview?

In order to protect your identity, we will use a pseudonym to refer to you during the study. Do you have a name that you would like us to use or would you prefer that we pick one? What pronouns would you like us to use for you?

As a reminder, participation in this interview is voluntary. You may decide not to participate at any time during the interview.

Great, thank you again!"

Interview Questions

Understanding participants thoughts on DBER

1. To help us get a better understanding of your position, could you share your obligations for research/scholarship, teaching, and service?

    - What counts as research/scholarship for the purpose of tenure and promotion?
    - How do your institution and department value STEM education research/scholarship?
    - How does this compare with your personal definition of success for STEM education research/scholarship?

2. What excites you about STEM education research? You mentioned (XXX) in your pre-interview survey, tell us more about that.

3. How would you define STEM education research?

    - Do you believe you have conducted STEM education research? Why or why not?

- (Optional follow-up) Do you think the STEM education research community would call what you're doing STEM education research? Why or why not?

Experiences in DBER

1. Could you tell us about some of your experiences with STEM education research?
   - (If they don't have any experience) What project would you like to do? When you imagine doing that research, what does it entail?
   - Which classes have you tried this in?
   - Would scholarly communication from this work (like a publication) support your tenure package?
   - In the pre-interview survey you mentioned (XXX), tell us about that experience!
   - Your CV says you were involved in (XXX), could you tell us about that?
   - Are there any other STEM education research activities you have led or participated in that you haven't shared yet (grants, data collection, analysis, program evaluation, etc.)? Could you talk a bit about your role in (this activity)?
2. And then what happened?
   - Was that a good experience for you?
   - What kinds of feedback did you get?
   - What have been your prior experiences with other DBER people?
   - Did you feel welcome? Did you feel like you could ask them basic questions?
   - Do you still work on that project?

Perception of DBER

1. What is your current DBER community?
   - What kind of support do you have for your DBER work (community, supportive colleagues/administrators, financial etc..)?

- Do you have any mentors?
- What kind of support do you wish to have for your DBER work?
- Are you planning to go to specific conferences in the near future (example: RUME)?

2. Have you

   - participated in a DBER conference or workshop?
   - worked on a DBER project with more experienced DBER people?
   - submitted a paper or poster in DBER?

3. What are some challenges you are encountering with the field?

Identity

1. How do you describe your current professional identity? Do you describe yourself as a DBER researcher? Why or why not?

2. How do you relate different aspects of your professional identity to your DBER work?

   - How do you feel DBER relates to your teaching?
   - How does being an instructor help you be a better DBER person? How does DBER help you be a better instructor? Is this important to you?

Wrap up

1. (At 50 min:) I'm mindful of your time; do you need to go right at (XX time)?

2. Before we close, is there anything you'd like to add or anything we should have asked you about, but didn't?

3. Are there any questions that you have for us?

" Thank you so much for your time! This was very useful and we really appreciate it."

Appendix D

Interview Protocol about Informal Physics Experiences

Set-up and introduction for all interviews

(Gallery view. Open up the Chat window, make it visible.)

“Hi, I’m NAME. Thanks for taking the time to talk to us today!

Just to refresh your memory, the goal of this project is to understand how we can better support the informal physics community (practitioners and researchers). We are interested in talking to you because you have experience with informal physics education. We would like to understand your successes, challenges, motivations, and needs when engaging in informal physics.

Before we begin: Do you have any questions about the consent form or this project?

With your permission we would like to record this interview to help us conduct more accurate data analysis. Can we record this interview?

(Make sure in Gallery view; Check that recording has started.) Just to have your permission on the recording, do you agree to having us record this interview?

In order to protect your identity, we will use a pseudonym to refer to you during the study. What pronouns would you like us to use for you? Can we use your identified pronouns for your pseudonym?

As a reminder, participation in this interview is voluntary. You may decide not to participate at any time during the interview.

Great, thank you again!"

Semi-structured interview (1 hour long)

Understanding participants' thoughts on informal physics

To all:

1. There are many terms used for informal physics education, outreach, and public engagement. What terms do you use to refer to in your work? How do you define that term?

   We use the term "informal physics education" to refer to activities outside formal schooling where facilitators and audience are mutually engaged, exchanging information and knowledge about physics. Sometimes we use the terms "public engagement" or "outreach" interchangeably with informal physics education. For the rest our discussion, I am going to use [insert their choice of terminology].

2. What excites you about informal physics education and/or research?

If in academia ask:

1. To help us get a better understanding of your position, could you give us a broad overview of your current professional obligations and involvement in public engagement? [Make sure to probe if they are mainly on the practitioner side of public engagement, or if they are engaging in any research or scholarship in that space]

2. (Ask the following as relevant, based on their response to question 1)

   - What counts as research/scholarship for the purpose of tenure and promotion?
   - How do your institution and department value informal physics education activities/programs? How do they value research/scholarship on informal physics education?

3. What is your personal definition of success for informal physics education activities and research/scholarship?

If not in academia ask:

1. To help us get a better understanding of your position, could you give us a broad overview of your current professional obligations and involvement in public engagement?

2. What is your personal definition of success for informal physics education activities and research/scholarship?

Experiences in informal physics education/research

1. Could you tell us about some of your past experiences with informal physics education and/or research?

   - (If they don't have any experience) What project would you like to do? When you imagine doing public engagement/outreach, what does it entail?

   - Are there any other activities you have led or participated in that you haven't shared yet (events/programs, grants, data collection, analysis, program evaluation, etc.)? Could you talk a bit about your role in this activity?

2. Present

   - What are you currently actively involved in as it relates to informal physics education?

   - Have you received any training or resources for your public engagement work?(and research, if applicable)

   - How do you evaluate/assess your public engagement activities?

   - How do you feel about your work?

3. Future

- What comes next for your involvement in public engagement?
- What skills do you hope to develop in the future?
- What are some of your goals for your professional development as it relates to your informal physics education work/research?

Perception of informal science education community: challenges and needs

1. What is your current informal physics education/research community?
2. What kind of support do you have for your work (community, supportive colleagues/administrators, financial etc..)?
3. What kind of support do you wish to have for your work?
4. What are some challenges/barriers you are encountering with engaging in public engagement activities?
5. What would you need to overcome those challenges?
6. What kind of support would be most helpful to you?
7. What kind of skills/specific training would be most helpful?
8. What kind of resources would be most helpful?

Identity

1. How do you describe your current professional identity? Examples (if needed): physicist, physics teacher, practitioner... How do you relate different aspects of your professional identity to your informal physics work? How do you relate informal physics to your career? How does informal physics inform your professional development? How does informal physics inform your professional advancement? Examples (if needed): rewards, recognition, promotions etc

Wrap up

1. As someone who has experience in informal physics outreach and activities, who do you suggest reaching out to participate in gathering information about the needs of practitioners and researchers engaged in informal science education? If you have anyone you would recommend and/or could be interested, please let us know and feel free to circulate this survey.

2. (At 55 min:) I'm mindful of your time; do you need to go right at (XX time)? Before we close, is there anything you'd like to add or anything we should have asked you about, but didn't?

3. Are there any questions that you have for us?

"Thank you so much for your time! This was very useful and we really appreciate it."

Semi-structured interview (30 minutes long)

To all:

1. There are many terms used for informal physics education, outreach, and public engagement. What terms do you use to refer to in your work? How do you define that term?

   We use the term "informal physics education" to refer to activities outside formal schooling where facilitators and audience are mutually engaged, exchanging information and knowledge about physics. Sometimes we use the terms "public engagement" or "outreach" interchangeably with informal physics education. For the rest our discussion, I am going to use [insert their choice of terminology].

Experiences in informal physics education/research

1. Could you tell us about some of your past experiences with informal physics education and/or research?

   - (If they don't have any experience) What project would you like to do? When you imagine doing public engagement/outreach, what does it entail?

- Are there any other activities you have led or participated in that you haven't shared yet (events/programs, grants, data collection, analysis, program evaluation, etc.)? Could you talk a bit about your role in this activity?

2. Present
   - What are you currently actively involved in as it relates to informal physics education?
   - Have you received any training or resources for your public engagement work?(and research, if applicable)
   - How do you evaluate/assess your public engagement activities?
   - How do you feel about your work?
3. Future
   - What comes next for your involvement in public engagement?
   - What skills do you hope to develop in the future?
   - What are some of your goals for your professional development as it relates to your informal physics education work/research?

Perception of informal science education community: challenges and needs

1. What is your current informal physics education/research community?
2. What kind of support do you have for your work (community, supportive colleagues/administrators, financial etc..)?
3. What kind of support do you wish to have for your work?
4. What are some challenges/barriers you are encountering with engaging in public engagement activities?
5. What would you need to overcome those challenges?

6. What kind of support would be most helpful to you?
7. What kind of skills/specific training would be most helpful?
8. What kind of resources would be most helpful?

Wrap up

1. As someone who has experience in informal physics outreach and activities, who do you suggest reaching out to participate in gathering information about the needs of practitioners and researchers engaged in informal science education? If you have anyone you would recommend and/or could be interested, please let us know and feel free to circulate this survey.
2. (At 25 min:) I'm mindful of your time; do you need to go right at (XX time)? Before we close, is there anything you'd like to add or anything we should have asked you about, but didn't?
3. Are there any questions that you have for us?

"Thank you so much for your time! This was very useful and we really appreciate it."