A Professional Development Program for Emerging STEM Education Researchers

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Abstract

In this evidence-based practice paper, we discuss design rationale, implementation and evidence from a professional development program for emerging education researchers (PEER). Many STEM faculty, trained only in disciplinary research, transition into research on the teaching and learning side of their discipline, with transitions occurring after typical formal training opportunities (e.g. grad school, postdocs) are over. There are limited opportunities for professional development when starting education research, and options are highly dependent on home institution type, department priorities, and faculty career stage. The PEER program helps faculty at any institution jumpstart their transition into discipline-based education research. Our goal is to help foster the next generation of STEM education researchers. PEER participants develop quality research projects, engage in targeted experiential work to develop their projects and skills, and collaborate and form a long-term support community of peers, mentors and collaborators. Over the last 8 years, more than 1000 participants have engaged in PEER field schools worldwide.

In this paper, we lay out the guiding principles of PEER: collaboration, responsiveness, communication, and playfulness. We situate the program within existing models for faculty professional development and describe the available modalities of PEER field schools: extended introductory in-person field schools (3-5 days), online or in-person gateway workshops (1.5 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. Drawing on evidence from interviews and surveys with STEM participants, we demonstrate the impact of different module activities on their professional skills, identity, and self-efficacy. We discuss the affordances and constraints of different formats and implications for faculty professional development. We prefer to present this work through a roundtable discussion, but we are also open to a lightning talk or a poster.

Introduction

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 paper 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 paper, 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.

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 [1]. 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 [2]. 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 evidence practices [3].

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 [4]. 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 [5]. 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 [6]. However many faculty highly value disciplinarity, and see a-disciplinary programs as not applying to them, or not meeting their needs [7]. 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 [8]. 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 [9]. 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 [10].

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 [11]. 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 [12] and APS research workshops [13]. 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 paper where PEER as a program fits in and its impact on emerging STEM education researchers.

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 [14]. 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 over 8 years. In its various modalities, PEER has taken place in locations 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.

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 [15]. 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 [16]. 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.

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.

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 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.

Figure 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.

Orient	**Data & access module**	**PEER principles**
Participants are oriented to the topic and learning goals associated with the workshop	Introduce a case study of a large enrollment course in which large changes are planned Brainstorm possible research questions for this context and share them with your group to discover common themes	*Playful*: brainstorm a wide range of possible questions *Collaboration*: Share with group to generate more ideas together
Learn	**Data & access module**	**PEER principles**
Participants learn about the key ideas of that topic	Revisit case study of large enrollment course Discuss possible data types based on participants' ideas Brainstorm possible data types for research questions and share them with your group	*Responsive*: Discuss possible data types based on participants' ideas. *Collaboration*: Share with group to generate more ideas together
Practice	**Data & access module**	**PEER principles**
Participants put into practice the skills and/or content knowledge they just learned	Introduce case study about teaching practices changes Brainstorm possible data types and research questions and share them with the group Generative writing on their own projects focusing on the kinds and amount of data, and how to realistically gather/analyze data	*Playful:* brainstorm and refine possible data types and research questions *Collaboration*: Share with group to generate more ideas together *Communicative*: Write about one's project in relation to workshop topic
Connect	**Data & access module**	**PEER principles**
Participants connect workshop content with previous or next workshops at PEER and broader perspectives	Reflecting and connecting with research process workshops about how data changes research questions	*Responsive:* Discuss the connection between this workshop and the previous one based on what participants did and discussed in this workshop

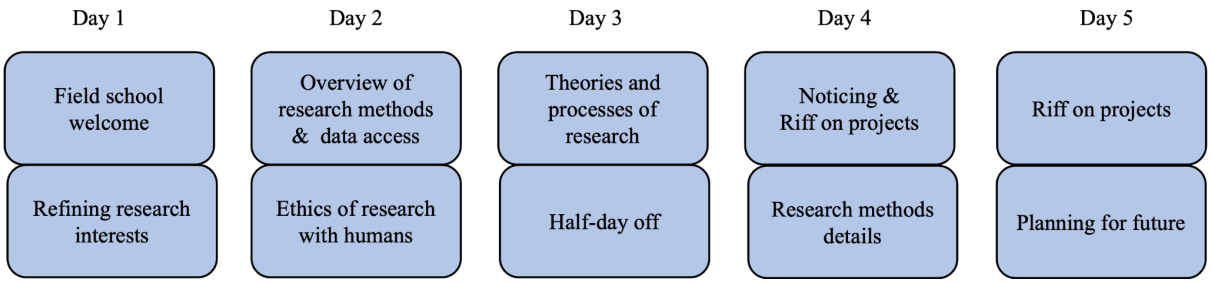
As we can see in Figure 1, in practice, the module begins by orienting participants through a case study linking research questions to appropriate methods where participants brainstorm ideas and share in small groups their ideas (orient phase). In response to ideas elicited by participants, facilitators 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 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).

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

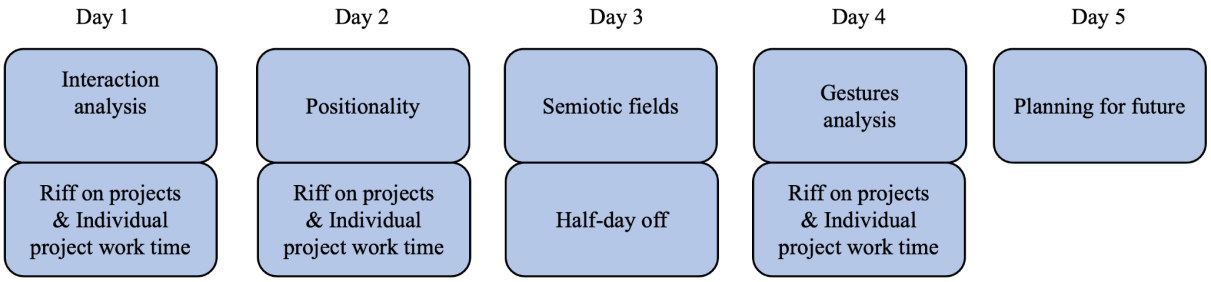


The online or in-person gateway workshops (1.5 hours or 3 hours) provide an entry point for communities getting started in STEM education research. The typical flow of this modality is illustrated in Figure 3. The typical enrollment in this modality ranges from 50 to 300 participants. As of the end of 2022, PEER has run 3 virtual gateways and is planning an in-person gateway in summer 2023, as well as 2 virtual gateways in 2023.

Figure 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.

The new advanced in-person field schools (5 days) follow-up introductory in-person field 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 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 a quantitative one for 2023.

Figure 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.



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.

Impact of PEER on participants

Research from several iterations of PEER, where we collected pre and post-interview with participants, show the affordances and constraints of various implementations and the perceived value of the field schools to the participants.

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 [17]. 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 [18]. 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 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 [19]. 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 [20].

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.*" 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.

Implications for professional development of faculty

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 [19]. 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 [18]. 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.

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.

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